Geophysical characterization of onsite wastewater treatment system effects on groundwater quality, eastern North Carolina

By

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Major Department: Geological Science

Abstract

Onsite wastewater treatment systems (OWS) are a potential non-point source of pollution that can result in water quality degradation in groundwater and surface water. Locating OWS wastewater plumes in the subsurface often requires extensive site instrumentation and monitoring. The application of capacitively coupled resistivity (CCR) surveys offers a time efficient method to image wastewater plumes and thus may help in the design of groundwater monitoring networks. Additionally, while most OWS permits provide the general location of the system components, the exact locations of the OWS drainfield trenches are not always displayed relative to a benchmark, and modifications to the system (and location) are not always recorded. Ground penetrating radar (GPR) can be used to identify drainfield trenches in real time in the field. The current study utilized seven OWS in Pitt and Craven Counties, located in the Inner Coastal Plain of North Carolina. CCR and GPR surveys were conducted in conjunction with laboratory analysis of water samples and environmental water quality readings collected in the field on three survey dates. The field study period was from June 2012 – May 2013. CCR survey drainfield resistivity values $\leq 250\ \Omega$.m and corresponding groundwater specific conductivity values $\geq 200\ \mu$S/cm were indicative of wastewater plumes and the influence of wastewater on groundwater quality detected up to approximately 15 m from the drainfield.

Ultimately, the results from this study provide further insight for CCR applicability to detect onsite wastewater treatment system effects on shallow groundwater quality. GPR 3D surveys and 2D transects were successfully used to identify active and de-activated drainfield trenches that matched with the locations determined in the field using a tile drain probe and on the OWS permit. Additional structures identified at a residential site using the surveys and transects included a French drain and two low attenuation structures not listed on the permit. This research demonstrates the use of GPR to efficiently locate OWS components. The dual application of both geophysical methods creates an opportunity to reduce costs and time spent at a site as well as provides a non-intrusive approach to better quantify the extent of the influence onsite wastewater inputs have on shallow groundwater quality.

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by

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

BG - Background

CCR - Capacitively Coupled Resistivity

CCWD - Craven County Water Department

DENR-Department of Environment and Natural Resources

DF – Drainfield

DG –Downgradient, within the OWS drainfield flow path

DW-Drinking Water

EC-Electrical Conductivity (Groundwater, Surface Water, or Wastewater Specific Conductivity)

EMI-Electromagnetic Induction

GPR - Ground Penetrating Radar

NH_4 - ammonium

NO_2 - nitrite

NO_3 - nitrate

NRWSA - Neuse Regional Water and Sewer Authority

OSP-Outside Flow Path

OWS - Onsite wastewater treatment system or Onsite wastewater treatment systems

PO_4 –phosphate

SW –Surface Water

TDN-Total Dissolved Nitrogen

WRRI-Water Resource Research Institute

Introduction

In the United States approximately 53% of assessed rivers and streams and 67% of assessed lakes, reservoirs, and ponds are impaired (USEPA, 2014). States report that non-point source (NPS) pollution remains a leading cause of water quality impairment (USEPA, 2014). NPS pollution or diffuse pollution may be emitted from a wide range of sources that are not regulated. In the United States, sources of NPS pollution linked to the degradation of water bodies include agriculture, atmospheric deposition, runoff, municipal discharges and contributions from on-site wastewater treatment systems (OWS) (USEPA, 2014). In eastern North Carolina, OWS are the predominant source of wastewater treatment in rural areas with approximately 60% of residences dependent on OWS for wastewater treatment and disposal (Pradhan et al. 2007). North Carolina’s 20 coastal counties are expected to experience a 31% population increase from 2013-2033 (NCOSBM, 2013). Future population growth along the coast is expected to place development pressure on regions, especially rural areas, relying on OWS for wastewater treatment resulting in greater wastewater discharges (NCOSBM, 2013).

OWS reduce the potentially harmful, elevated concentrations of nutrients and pathogens characteristic of OWS drainfield effluent (Humphrey et al. 2010). Decentralized OWS consist of 3 main components including a septic tank, distribution box, and drainfield (Figure 1).

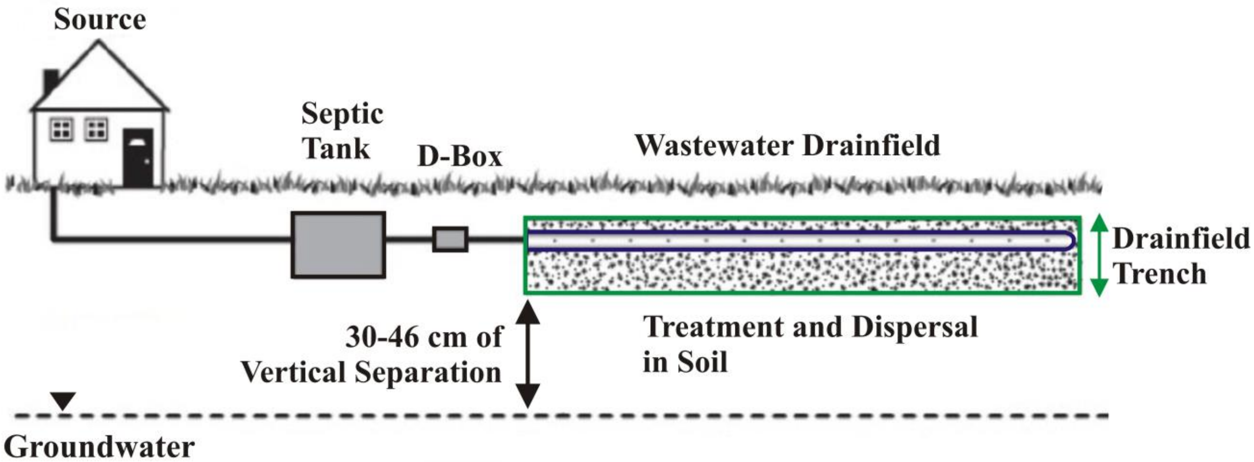

Figure 1. Generalized schematic of a decentralized OWS (Modified from Lindbo, 2005 and Smith, 2013). The 30-46 cm vertical separation between the bottom of the gravel drainfield trench and the water table is a North Carolina state requirement for sandy (30 cm) (Section. 1955, 1990).

Wastewater flows from the source (house) to the septic tank. Generally, the initial treatment of the wastewater within the septic tank is the primary treatment. When wastewater enters the septic tank denser solids sink and form a sludge layer along the bottom of the tank, and less dense fats, greases and oils float above the wastewater as a scum layer. The primary treatment of wastewater within the septic tank consists of the removal of solids via density differences, anaerobic digestion of organic material, and the mineralization of organic N to NH_4. Wastewater in the tank is displaced through system usage and the effluent flows into the drainfield. Effluent in the drainfield infiltrates soil, and eventually percolates through the subsurface where it undergoes various physical, chemical and biological treatment processes. Aerobic treatment may occur beneath the drainfield trenches if there is sufficient vertical separation from OWS to groundwater (Humphrey et al. 2013).

In the United States, OWS contribute approximately 800 billion gallons of wastewater per year to the subsurface and are frequently reported as the cause of groundwater contamination (Yates, 1985). Inadequately treated wastewater in the subsurface can contaminate shallow groundwater and/or surface water bodies and has been associated with water quality impairment in coastal North Carolina and throughout the United States (Table 1). In coastal North Carolina, Cahoon et al. (2006) associated the highest fecal coliform (bacteria) concentrations collected at sites in an estuarine watershed with OWS systems (Table 1). The elevated bacteria concentrations were attributed to high system densities, improper OWS system performance, and poor soil suitability (Cahoon et al. 2006).

Table 1. Water quality research collected in coastal settings in which wastewater indicators were used to locate areas in which groundwater (GW) and/or surface water (SW) bodies were impacted by wastewater inputs.

Country	State or Province	Year	Wastewater Indicator	Water Body Impacted	Author
Australia	Queensland	2005	Bacteria	GW and SW	Ahmed et al.
Canada	Ontario	1996	Nutrient	GW	Harman et al.
Canada	Point Pelee	1998	Nutrient	GW	Ptacek
United States	Florida	2001	Bacteria	GW and SW	Lipp et al.
United States	Florida	2002	Nutrient	GW	Corbett et al.
United States	North Carolina	1997	Virus	GW	Scandura and Sobsey
United States	North Carolina	2002	Nutrient	GW	Buetow
United States	North Carolina	2006	Bacteria	GW and SW	Cahoon et al.
United States	North Carolina	2012	Nutrient	GW and SW	Humphrey et al.
United States	Virginia	2004	Nutrient	GW	Reay

Research by Lipp et al. (2001), Ahmed et al. (2005), and Cahoon et al. (2006) associated OWS derived bacteria with surface water contamination in coastal settings (Table 1). Studies by Harman et al. (1996), Ptacek (1998), Corbett et al. (2002), and Humphrey et al. (2012) used nutrients to locate and track wastewater plumes for varying distances away from the systems and assessed the impacts of OWS on groundwater downgradient of the systems (Table 1). Specifically, Harman et al. (1996), in coastal North Carolina, found that nutrient enriched OWS plumes can migrate distances greater than 100m from OWS drainfields in sandy sediments. Corbett et al. (2002) found that nitrogen and phosphorus derived from an OWS can be transported by shallow groundwater distances greater than 23 m on a barrier island in Florida. Researchers found that nutrients in groundwater remained above natural levels in the sandy aquifer system at a majority of the residential study sites (Corbett et al. 2002). Corbett et al. recommended a setback (offset) distance increased from 23 to 50 m in order to reduce nutrient concentrations to natural levels based on the current septic system density on the island.

Offset or setback distances between OWS drainfields and water bodies are implemented to provide effective treatment of wastewater constituents and prevent contamination of water resources attributed to OWS wastewater inputs. The setback distances are dependent on the system design flow and the surface water body. In North Carolina, OWS with design flows ≤ 11,340 liters/day have a minimum setback of 15 m between the system and surface water bodies (Section. 1900, 2007). OWS with design flows exceeding 11,340 liters/day have a minimum setback of 30 m between OWS and surface water bodies (Section. 1900, 2007). The minimum 15 m offset regulation is based on the assumption that a 15 – 30 m subsurface flow path will provide adequate treatment of wastewater constituents necessary to prevent harmful contamination of surface water bodies. In some situations, the minimum setback distance is increased to protect surface water bodies including outstanding resource waters. However, research has shown wastewater nutrient and bacteria migration distances can exceed 15-30 m setback distances in sandy coastal plain settings. The minimum setback distances of 15 -30 m may be inadequate when attempting to prevent surface water quality impairment and return nutrient levels to natural (Corbett et al. 2002 and Harman et al. 1996).

Previous studies have used networks of piezometers to assess groundwater quality at discrete points to monitor OWS wastewater influence on groundwater and surface water bodies. Installing and monitoring piezometers can be a resource intensive process. Generally, piezometers are installed at various locations and depths to capture the vertical and lateral movements of the groundwater and to locate and characterize the areas influenced by OWS inputs. Groundwater influenced by wastewater typically has elevated specific electrical conductivity that may be detected as areas of low resistivity on geophysical surveys (Amidu and Olayinka, 2006; Lee et al. 2006; and Smith, 2013). Table 2 shows the studies similar to the current research in which geophysical techniques were used to areas of low resistivity within close proximity to the wastewater inputs.

Table 2. Modified from Smith (2013). Recent studies that applied geophysical techniques as a non-intrusive means to delineate OWS wastewater plumes in various geologic settings. Roy et al. 2009 reported the system discharged 12,000 L/day of treated wastewater into the subsurface. Smith (2013) was the only site to combine geophysical surveys with ground and surface water quality analysis at 2 sites.

Location	Sediment	Water table (mbgs)	Septic Tank Capacity (L)	Geophysical Method	Author	Year
Nigeria	Unconsolidated Clayey-Sand	≤10	Not Provided	Electrical Resistivity	Amidu and Olayinka	2006
United States	Glacial Till Derived Soil	1.2	4750	Electromagnetic Induction (EMI)	Lee et al.	2006
Canada	Glacial Boulder Till	0.5	Not Provided	EMI and CCR	Roy et al.	2009
U.S.	Unconsolidated Sand	3.6-7.2 0.6-2.5	37,800 and 73,827	CCR and GPR	Smith	2013

Related Research

Geophysical surveys conducted by Amidu and Olayinka (2006) at a campus in southwestern Nigeria found low resistivity values (less than 200 Ωm) within close proximity to the septic tank (Table 2). Researchers determined the low resistivity values were influenced by OWS inputs that were highest at locations nearest to the OWS input source. Amidu and Olayinka (2006) found that the resistivity values increased with increased distance from the wastewater inputs. Researchers also successfully correlated geophysical results with the conductivity values derived from the soil samples (Amidu and Olayinka 2006).

Lee et al. (2006) successfully used electromagnetic induction (EMI) surveys to locate a failed OWS drainfield and OWS wastewater plume at a residential site. The geophysical surveys were completed in conjunction with electrical conductivity data collection in order to ground truth the geophysical data (Lee et al. 2006). The electrical conductivity data was collected from soil sample analysis (Lee at al. 2006). Lee et al. 2006 recommended expanding the application of the geophysical method to other soils and environmental conditions in order to gain a broader view of the method's applicability in a range of environments (Table 2).

Roy et al. (2009) used GPR to determine the approximate location of a site's OWS components and CCR as a rapid assessment method to map the horizontal and vertical extent of subsurface regions characterized by elevated electrical conductivity (Table 2). The CCR survey values were supported by surface water analysis of samples collected nearby the CCR transects (Roy et al. 2009). Roy et al. (2009) recommended developing a methodology that utilized GPR and CCR survey data in conjunction with hydrological and ecological analysis of the study area.

Smith (2013) combined GPR and CCR geophysical surveys with water quality analysis to assess the OWS drainfield at 2 schools in coastal North Carolina. The study successfully utilized GPR to locate OWS components and CCR to identify OWS derived wastewater plumes below the drainfields in the sandy surficial aquifer. Smith (2013) assessed the parameters that may influence the CCR resistivity values including: specific conductivity, hydraulic conductivity, porosity, and water level values (Loke, 2004). Smith (2013) found that a strong relationship existed between groundwater specific conductivity and CCR survey resistivity values. The 2 schools' resistivity data were most responsive to changes in groundwater specific conductivity when the values were significantly different across background and drainfield areas (Smith, 2013). Smith (2013) determined that the drainfield resistivity values $\leq 250\ \Omega$.m and corresponding groundwater specific conductivity values ≥ 200 μS/cm were characteristic of the wastewater plume below a drainfield.

Current Study

The current study broadens the scope of Smith (2013) by expanding the study area at the Smith (2013) 2 school sites and incorporating 5 sites with smaller OWS (Appendix A). The 5 sites with smaller OWS were expected to have wastewater inputs more representative of residential systems (Appendix A). The purpose of the current study was to utilize GPR and CCR in conjunction with groundwater quality analysis at multiple sites in the surficial aquifers of the Inner Coastal Plain, North Carolina. Sites were selected across a range of wastewater maximum design flows and water table conditions.

The objectives of this study were to determine: 1) if CCR surveys could detect resistivity responses to increases in groundwater specific conductivity associated with wastewater inputs to the drainfields across a range of sites; 2) if resistivity responses to wastewater inputs (and associated changes in groundwater specific conductivity) could be detected downgradient of the drainfield; and 3) if GPR could locate OWS system components across a range of drainfield sizes. Overall, these objectives can help determine if geophysical approaches can provide useful information for characterizing OWS and their impacts on shallow groundwater quality in coastal watersheds.

The hypotheses for this study were: 1) resistivity response to increases in groundwater specific conductivity will be detected at the sites with large OWS relative to the sites with small OWS; 2) inverse resistivity responses to increasing groundwater specific conductivity will be detected downgradient of the drainfield at sites with elevated groundwater specific conductivity values within the drainfield; and 3) GPR can accurately identify the location and orientation of active and inactive OWS drainfield trenches across a range of system sizes.

Study Area

NCCP Geology and Hydrology

The geology of the NCCP (North Carolina Coastal Plain) may be characterized as a gently southeastward dipping and thickening homocline composed of sediments and sedimentary rock ranging in age from Cretaceous to Recent resting on an underlying crystalline basement complex of Paleozoic age rocks (Lautier, 2001 and Smith, 2013). The hydrogeological system of the NCCP consists of 10 major aquifers composed of permeable sand, gravel, and limestone layers that are separated by 9 confining units typically composed of less permeable sediments including silt and clay (Winner and Coble, 1996). The upper most aquifer of the 10 aquifers is the water table aquifer or unconfined/surficial aquifer and the bottom of the system is underlain by crystalline bedrock (USGS, 2012). The remaining 9 confined aquifers from basement to land surface begin with the Lower Cretaceous, Lower Cape Fear, Upper Cape Fear, Black Creek, Peedee, Beaufort, Castle Hayne, Pungo River, and Yorktown aquifers (USGS, 2012 and Winner and Coble, 1996). The surficial aquifer is the uppermost of the aquifer system and is composed of sands, silts and clays. The surficial aquifer is most easily contaminated because it often does not have confining layers that separate it from potential contaminant sources at the land surface (Farrell et al. 2003). Most often in an unconfined aquifer system, the aquifer is recharged through rainfall infiltration into the subsurface and may discharge into streams and local surface water bodies maintaining base flow (Ator et al. 2005 and Denver et al. 2014). Contaminants transported with groundwater may be translated to adjacent surface waters and affect surface water quality (Ator et al. 2005 and Denver et al. 2014). With respect to the current study, OWS that discharge wastewater to the surficial aquifer can provide additional recharge. Generally, the residential water source is from a deeper aquifer or a municipal water supply. In the current study the water supply source for each site is provided in the site descriptions in the Methods section.

Local Hydrology

The current study was conducted in the NCCP and focused on the surficial aquifer where OWS systems are typically located. The surficial aquifer in the NCCP is dominated by Quaternary aged sediments consisting of unconsolidated sand, silty, and clay sediments (Lautier, 2001). The base of the unconfined aquifer is typically 3 to 6 m below the land surface, and was estimated to be approximately 4 m thick by the North Carolina Department of Environment and Natural Resources Division of Water Quality (NCDENRDWQ) during the installation of monitoring well R23X5 in Craven County (Smith, 2013). Winner and Coble (1996) determined the base of the unconfined/surficial aquifer to range from approximately 2.3-5.49 m at different research stations in Craven County and 8m at the Bethel Research station in Pitt County.

Three study sites were located in the Neuse River Basin, which drains an area of 16,108 km^2, in the NCCP. The Neuse River Basin consists of 18 counties. The Neuse River Basin population is expected to increase by 44% from 2000 to 2020 and exceed 2,000,000 people in 2020 (NC DENR, 2009). Nonpoint source runoff from a variety of land use practices and nutrient loading is identified as the primary source of impacted surface waters and water quality impairment in the Neuse River Basin (NC DENR, 2009). Two of the study sites are located in the Lower Neuse River Basin and 1 in the Middle Neuse River Basin (Figure 2). In the Middle Neuse River Basin the major land uses are agriculture (34.4%), forest (26.2%), wetlands

(19.4%), other herbaceous areas (11.8%), urban (8.2%) and bare earth (0.1%) (NC DENR, 2009). In the Lower Neuse River Basin the major land uses are wetlands (35.1%), forest (24.9%), agriculture (18.5%), other herbaceous areas (11.3%), urban (6.2%) and bare earth (0.1%) (NC DENR, 2009).

Four study sites were located in the Lower Tar-Pamlico River Basin (Figure 2). The Lower Tar-Pamlico River Basin covers an area of 14,000 km^2 and the estimated population in basin is expected to exceed to 170,000 people in 2020. The land uses for the Lower Tar-Pamlico River Basin are agriculture (37.7%), forest (26.9%), wetlands (14.5%), other herbaceous areas (13.01%), developed (8.12%) and bare earth (< 0.1%) (NC DENR, 2010). Non-point source pollution and urban development stressors continue to be an issue for the basin, which was categorized as a Nutrient Sensitive Water in 1989 due to the high number of fish kills and large algal blooms present (NC DNRCD, 1989). The population within the Neuse River and Tar-Pamlico basins is expected to increase, and urban development has the capacity to increase stressors to water quality by increasing nutrient loading from runoff to local streams (NC DENR, 2009 and 2010).

All study sites are located within basins that reside in the NCCP. The Neuse and Tar-Pamlico watersheds have similar mean annual precipitation and mean air temperature. Historical mean annual precipitation and temperatures within the study area were recorded from 1899 – 2012 at the Kinston 5 SE gauging station (ID# 314684) with 126 cm/year and 16.4º C and the Greenville 2 gauging station (ID#313638) with 124 cm/year and 16.2º C (SRCC, 2014).

Methods

In order to address the study objectives, geophysical, groundwater, and surface water monitoring were conducted throughout the study period, June 2012 – May 2013, at 4 main focus sites and 3 supplemental sites that utilized OWS. The 4 focus sites included: the high school, elementary school, education center, and residential site (100). The supplemental sites included: residential sites 200, 300, and 400. The sites were selected based on site availability and variability in OWS size. The sites were relatively grouped based on OWS size.

Summary of Site's OWS

The school sites had larger OWS and the education center and residential sites had smaller OWS (Table 3). The OWS permit information and copies of permits are listed in Appendices A and B.

Table 3. Excerpt of site specific OWS information from Appendix A. The sites were grouped based on generalized system size that was determined using the drainage area, number of drainfield pipes, and the maximum design flow. The sites with 2 dates listed show the installation date for the de-activated system and then the date of for the active system.

Generalized System Size	Site	System Installation Year	Max Design Flow (L/d)	Number of Drainfield Trenches	Drainfield Field Area (m^2)
Large OWS	High School	pre-1999/1999*	73827	32	1115
	Elementary School	1987	37800	32	892
Small OWS	Residential 100	1998/2003*	1360	6	155
	Residential 200	1977/2004*	1360	4	84
	Residential 300	1986	1360	4	111
	Residential 400	1999	1360	4	111
	Education Center	2012	1512	3	59

In the current study, the sites with large OWS had high OWS maximum design flows (> 11,340 L/day) (Table 3). The sites with small OWS had low OWS maximum design flows (< 1,600 L/day) (Table 3). The maximum design flow is the maximum number of liters per day the system is designed to handle. The OWS maximum design flow was used as a general indicator of expected wastewater inputs at the sites. Increased wastewater inputs were expected at the school sites due to large OWS sizes and subsequent high maximum design flows (>11,450 L/day). Lower wastewater inputs were expected at the education center and residential sites due to the smaller OWS sizes and subsequent lower maximum design flows (< 1,600 L/day).

An outline of fieldwork including sampling methods and geophysical transect IDs with corresponding sampling and geophysical survey dates at all sites is located in Appendix Table C. Previous research completed at all sites including methodology, results, and discussion can be found in Iverson (2013), Smith (2013), and Humphrey et al. (2013).

Index Map

Individual site maps were created using an aerial base map supplied by NC ONEMAP in ArcGIS. Waypoints were collected for piezometers, GPR, and CCR survey locations, using a *Trimble* GPS and input into an ArcGIS aerial base map. The locations of all the sites are shown in Figure 2.

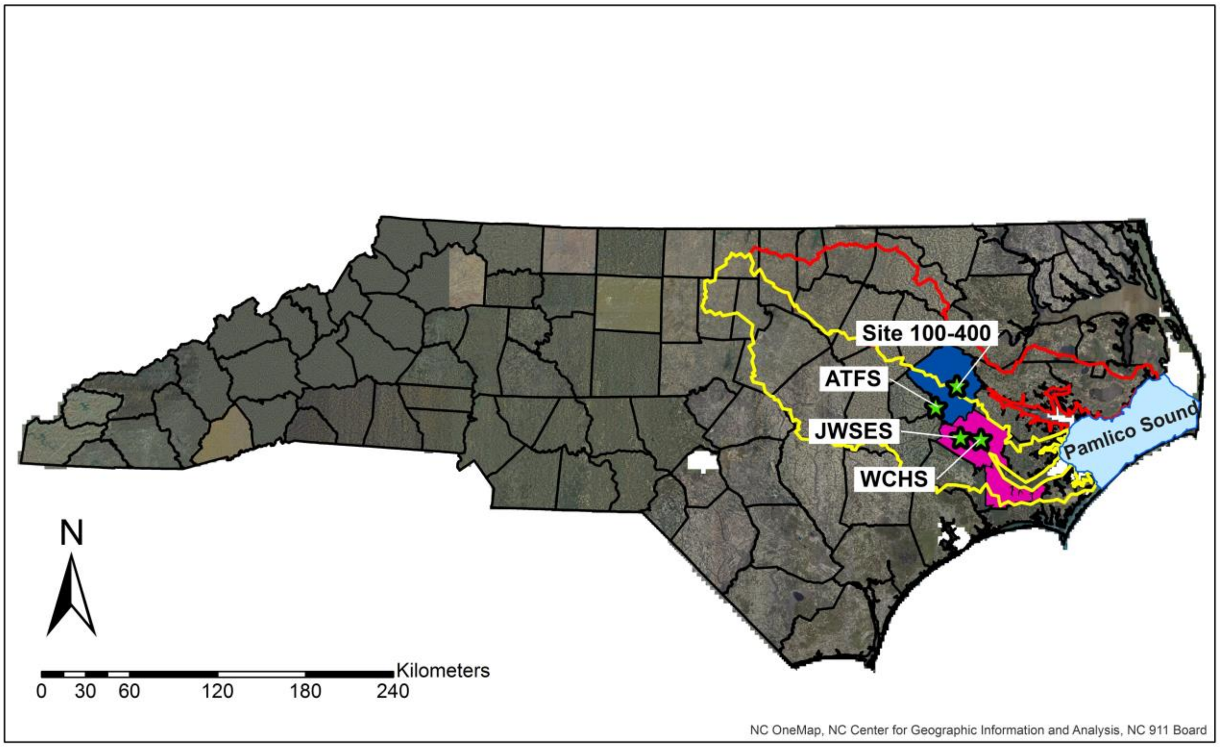

Figure 2. Index Map shows site locations (green stars) in coastal North Carolina. The Education center and Residential 100-400 are located in Pitt County (dark blue county). The elementary and high schools were located in Craven County (pink county). The Neuse River Basin and Tar River Basin were outlined in yellow and red respectively. The rivers discharge into the Pamlico Sound (blue filled in area).

Elementary School Site (OWS Size: Large)

The elementary school was referred to as James W. Smith Elementary School (JWSES) in Smith (2013). The elementary school is located approximately 4 km south of the Neuse River in Craven County, North Carolina (Figure 2). Water is supplied to the elementary school by the Craven County Water Department (CCWD). The CCWD utilizes groundwater that is extracted from the Late Cretaceous age Black Creek and Peedee aquifers (Smith, 2013). The elementary school OWS uses a pump to transport wastewater from the tank to the distribution boxes where it then gravity flows through the drainfield pipes and eventually percolates through the soil. The elementary school OWS consists of 2 distribution boxes each with 16 drainfield trenches that were 0.9 m x 0.3 m x 30 m and separated by approximately 2 m. The drainfield perimeter is approximately 38 m x 89m (Figure 3 and Appendix A and B1). The 2 systems operated on a dosing cycle. During a dosing period 1 system was active and the other was inactive. The average depth to the top of the drainfield trenches was 0.6 m (Smith, 2013).

The topography of the area upgradient and in the drainfield is gently sloping. The topography downgradient of the drainfield has an approximate 10 meter elevation relief that includes a riparian buffer. An unnamed tributary stream that drains to Core Creek is located approximately 40 m to the north of the drainfield (labeled “stream” in Figure 3). A nearby spring is located approximately 25 m north of the drainfield (Figure 3). The spring discharge flows overland approximately 15 m to converge with an unnamed tributary of Core Creek. Surface water samples were collected from the spring, spring stream interface and 5 m up and downstream of the interface.

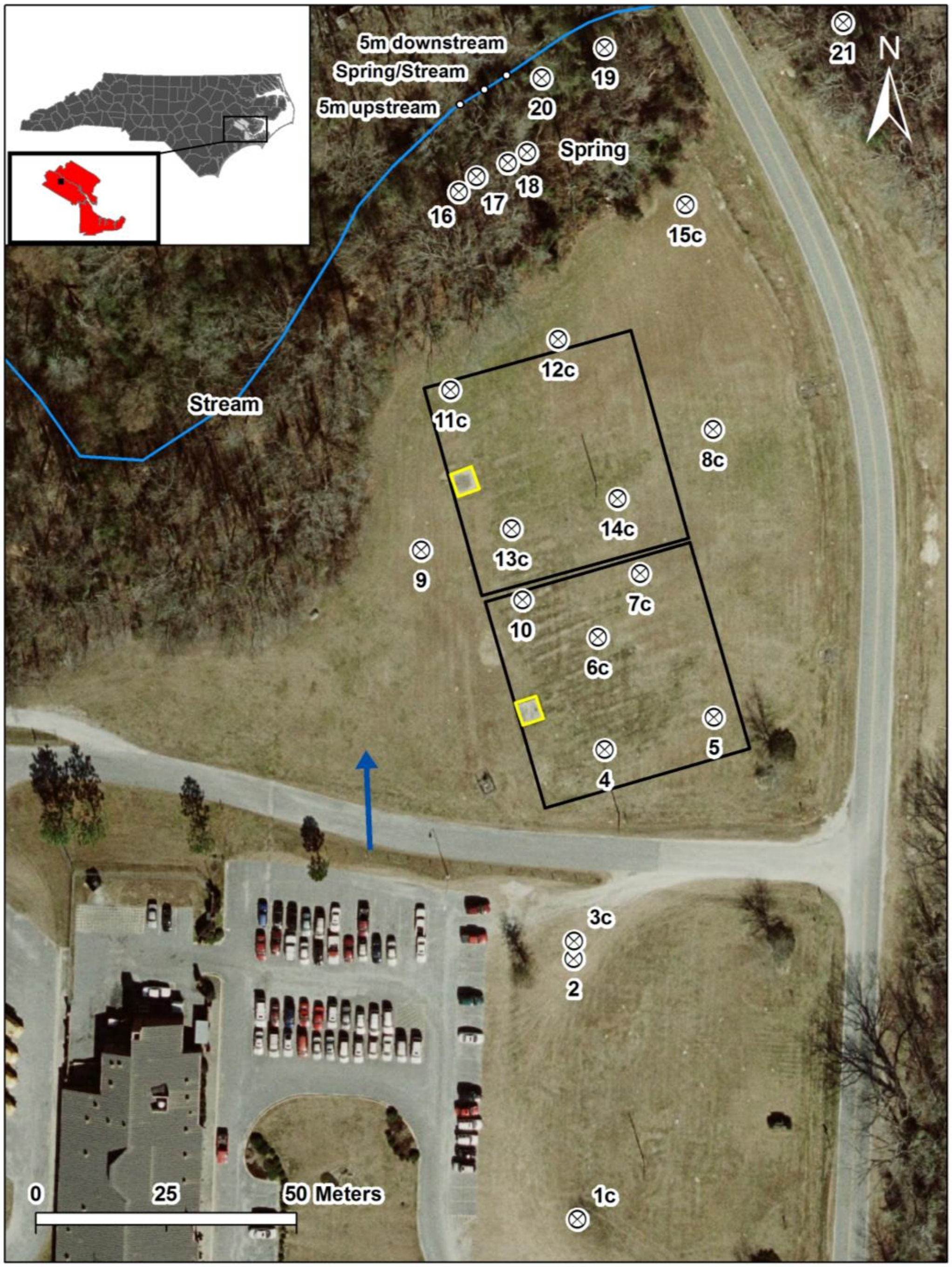

Figure 3. Site map of the elementary school with the approximate locations of the 2 active wastewater drainfields (solid black box) and the distribution boxes (yellow boxes). Piezometer sampling points are labeled with ID numbers. The "c" marks the core collection locations. A stream was defined by the blue line. The blue arrow indicated the general direction of groundwater flow (Figure M2). The location of the 3D and transect geophysical surveys are located in Appendix Figure H2. (Modified from Smith, 2013).

High School Site (OWS Size: Large)

The high school was referred to as West Craven High School (WCHS) in Smith (2013). The high school is located approximately 2 km north of the Neuse River in Craven County, North Carolina (Figure 2). CCWD supplies groundwater to the high school from the Late Cretaceous age Black Creek and Peedee aquifers. The high school uses a low pressure pipe (LPP) system for wastewater treatment and disposal. The OWS consists of 2 distribution manifolds each with 16 drainfield trenches that were 0.6 m x 0.3 m x 38 m and separated by approximately 2.1 m. Wastewater is pumped to the manifolds where under low pressure it flows through the drainfield trenches and eventually percolates through the soil for treatment (Figure 4). Adjacent to the 2 active drainfields is a de-activated drainfield with 16 drainfield trenches that were 0.6 m x 0.3 m x 38 m and separated by approximately 2.1 m (Figure 4 and Appendix A and B2). The average depth to the top of the drainfield trenches was 0.7 m (Smith, 2013). The depth from the surface to the top of the trenches was determined using a tile drain probe by Smith (2013). Water samples were collected from a small unnamed stream located along the northern boundary of the study area (Figure 4). Groundwater flow directions for the study period, June 2012 – May 2013, show a general flow direction to the northwest.

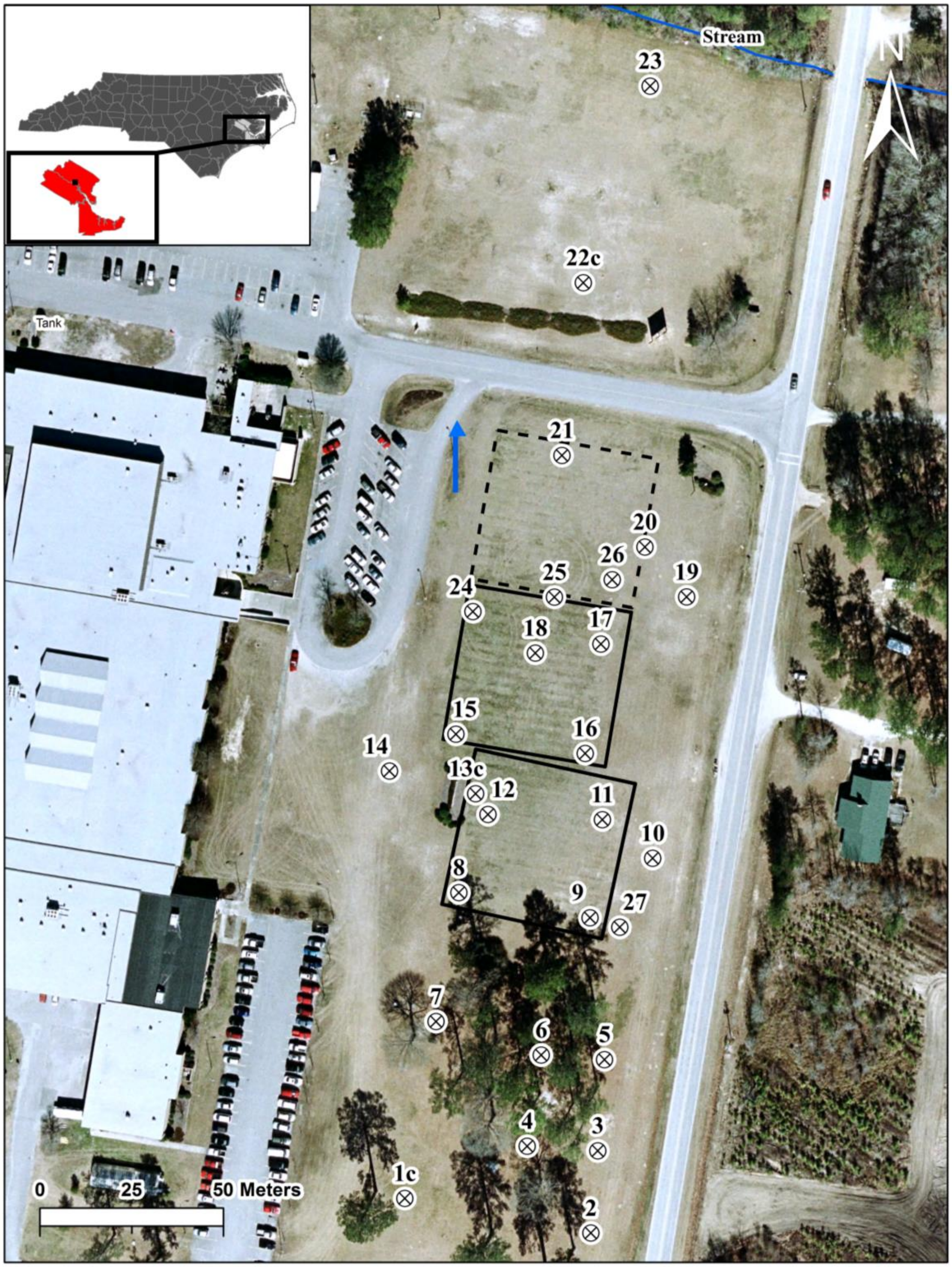

Figure 4. Site map of the high school with the approximate locations of the 2 active wastewater drainfields (solid black box) and 1 de-activated drainfield (dashed black box). Piezometer sampling points are labeled with ID numbers. The "c" marks the core collection locations. A stream is defined by the blue line. The blue arrow indicated the general direction of groundwater flow (Figure M1). The location of the 3D and transect geophysical surveys are shown in Appendix Figure H1. (Modified from Smith, 2013).

Education Center (OWS Size: Small)

The education center (A Time for Science (ATFS)) was located approximately 0.5 km from the Neuse River in Pitt County, North Carolina (Figure 2). The education center drainfield was located less than 0.5 km from Little Contentnea Creek that flows into Contentnea Creek and then into the Neuse River. Water is supplied to the education center by the Bells Arthur Corporation and extracted from 6 wells which draw from the Black Creek and Upper Cape Fear Aquifers. The education center also receives water from the Neuse River in Lenoir County, which is treated by the Neuse Regional Water and Sewer Authority (NRWSA). The education center OWS relies on a gravity flow system in which wastewater flows from the tank to the drainfield trenches (Figure 5). The education center drainfield has 1 distribution box and 3 drainfield pipes with (0.9m x 0.4m x 21 m) and 2 m of spacing between pipes (Appendix A and B3). The average depth to the top of the drainfield trenches was 0.46 m. The depth from the surface to the top of the trenches was determined using a tile drain probe. The OWS is approximately 120-130 m from three local surface water bodies. During the current study a piezometer network was installed in order to assess how an undisturbed site changes once an OWS is added and begins to disperse waste in the subsurface. The education center site was unique because it had sporadic use from various school groups. The sporadic use allowed for extended periods when wastewater discharge would cease (Humphrey et al. 2013). The education center generally hosted a 3 day event twice a month based on the education center's calendar (ATFS, (2014)). The education center OWS permit was approved on 10/17/2011, and the system was installed during February 2012. The first event held at the education center was listed on the ATFS public calendar as 2/28/2012 (ATFS, (2014)). The first survey date at the education center (3/23/2012) was conducted after the system was installed. The education center system was the newest installed system of the OWS in the current study (Appendix A).

Figure 5. Site map of the education center. The active wastewater drainfield location is represented by a black rectangle. Piezometer and surface water sampling points and ID numbers are shown. 3D geophysical study areas were not collected at this study site.

Residential 100, 200, 300 and 400 Sites (OWS Sizes: Small)

The residential 100-400 sites were located approximately 4-5 km from the Tar River in Pitt County, North Carolina (Figure 2). Water was supplied to the study areas from the Eastern Pines Water Corporation that relies on 10 deep wells located in the southeastern portion of Pitt County accessing the Black Creek, Upper Cape Fear, and Pee Dee aquifers and the NRWASA.

All residential sites' OWS relied on gravity flow from the tank to the distribution box to the drainfield pipes. In Appendix A and B4-6 the OWS permits, OWC location, drainfield types, etc. are listed for each site. The depth to the top of the drainfield trenches was 0.85 m at Residential 100 and 200, 0.55 m at Residential 300, and 0.64 m at Residential 400. The depth from the surface to the top of the trenches was determined using a tile drain probe.

The Residential 200, 300, and 400 sites are listed as supplemental sites and were only surveyed and sampled once during the study on 9/17/2012. Residential 100 was selected as the main focus residential site because the homeowners agreed to extend the study period to a year and the site already had extensive piezometer network already installed. Residential 100 had sandy clay loam soils (Lynchburg series) and a shallow water table in the drainfield (Humphrey et al. 2013). The site had an abandoned OWS located closer to the house that consisted of 6 drainfield trenches, 1 distribution box, 1 french drain, and an active system consisting of 6 drainfield trenches (Appendix A and B4). The Residential 100 individual drainfield trench sizes were 0.9 m X 0.15-0.2 m X 21 m with 2 m spacing between trenches. An unnamed tributary stream was located adjacent to study Residential 100 and 200 (Appendix H4 and H5).

Figure 6. Site map of study area at the Residential 100. The active wastewater drainfield is represented by a black solid line rectangle and inactive system in dashed black line rectangles. A stream location is shown by the blue line. Piezometer and surface water sampling points are shown.

Piezometer Instrumentation

The piezometers were installed to better evaluate the extent of OWS plumes at the sites. The piezometers were positioned upgradient, within, outside, and downgradient of the drainfield in order to collect depth to water-table and groundwater quality measurements to pair with resistivity estimates collected from CCR transects.

During previous research, piezometers were installed at the schools and residential sites (Smith (2013), Iverson (2013), and Humphrey et al. (2013)). For the current study, five additional piezometers were installed at the elementary school, to add to the 21 piezometers installed during Smith (2013). The total number of piezometers installed at the elementary school was 26. Nine additional piezometers were installed at the high school increasing the number of piezometers at the site from 28 to 37 piezometers. CCR surveys conducted by researchers in Smith (2013) were used to aid in additional piezometer instrumentation at the schools. The piezometers were installed at locations and depths that corresponded to areas of decreased resistivity on the CCR surveys conducted by Smith (2013).

The education center was the only site at which no previous research was completed, so piezometers were installed within the background, drainfield, and downgradient areas. The education center was outfitted with 17 piezometers, 9 of which were installed less than a month after the center was opened. When the first 9 piezometers were installed at the education center wastewater was not believed to have been discharged to the subsurface. This estimate was loosely based on the education center calendar of events and capacity of the septic tank. There was only 1 scheduled event that occurred prior to piezometer installations, and unless more than 3,785 liters of wastewater were generated during that event, then no effluent was discharged to the soil over that period. The remaining 8 piezometers were installed in August, 2012, and consisted of 1 shallow background piezometer, 1 shallow drainfield piezometer, and 6 downgradient piezometers located in a wooded area of the site. Shallow is a relative term and references the proximity of the piezometer's screened interval to the screened intervals of other piezometers in the nest.

Overall, a total of 29 piezometers were installed in the current study and a total of 93 piezometers, 9 surface waterbodies and 1 pipe were sampled from the main focus sites: schools, education center, and Residential 100. A total of 19 additional piezometers were sampled from Residential 200, 300, and 400 on 1 survey/sample date.

Piezometers were installed using a truck-mounted Geoprobe coring rig or a hand auger. The truck-mounted Geoprobe coring rig was used when space was available. The hand auger was used in areas that were too compact for the truck to fit or in areas near the drainfield trenches to prevent compaction. The piezometers consisted of 3.1 cm or 5.05 cm diameter pvc pipe with size corresponding connectors, caps, and 0.91 m drive point screens. Piezometers were installed so the screened interval intersected or was below the water-table to collect groundwater quality data at each site. Primer and glue were used to connect the pipes. Well pack sand was used to seal the space between the screened length of the piezometer and borehole. Bentonite, well pack sand, and local soil were used to seal the remaining space between the non-screened length of the piezometer and the borehole to prevent atmospheric water from influencing groundwater chemistry. Valve boxes were installed around the piezometer, flush with the ground surface to protect the piezometer from overwash and anthropogenic influence. Piezometers installed within the floodplain and in wooded areas extended approximately 1 m above ground.

At all sites, the first 3 piezometers were installed in order to determine the groundwater flow direction then additional piezometers were installed within, up and down-gradient of the drainfields. Piezometers installed upgradient of the drainfield were referred to as background (BG) piezometers. Based on the groundwater flow directions determined by the three point method the BG piezometers are not believed to be influenced by the site's OWS wastewater inputs (Heath, 1983). However, it is possible that upgradient OWS may influence BG piezometers, especially in high density neighborhoods. The piezometers installed within the drainfield (between drainfield trenches) were referred to as drainfield (DF) piezometers. The piezometers installed downgradient of the drainfield were listed as downgradient (DG) and outside of the OWS flow path (OSP).

The downgradient (DG) data sets were also divided into 2 groups based on the piezometer's location and distance from the drainfield. One group consisted of the piezometers located less than 15 m downgradient from the OWS active drainfield (DG ≤ 15 m). The second group consisted of the piezometers located greater than 15 m downgradient of the OWS active drainfield trenches (DG ≥ 15 m).

The schools, education center, and Residential 100 had at least 1 nested piezometer group that were used to assess the vertical groundwater flow in order to determine the groundwater recharge and discharge areas (Appendix Table E5). The nested piezometers were also used to assess the vertical extent of the wastewater plume at each site. The piezometer nest had piezometer ID numbers with an "s", "m" or "d", and the letters stand for shallow, medium, and deep, respectively. The letters indicate the relative depth of the screened interval with respect to the other piezometer's screened interval within the nest. The depth to bottom (DTB) of the screen for each piezometer was listed in Appendix F.

Lithology and Grain Size

Soil series specific to each site were collected from the soil reports and maps by the USDA National Resources Conservation Service using the online Web Soil Survey (2014). Based on the surveys the soil series, soil type, K_{sat}, and piezometers located within the soil series at each site are listed in Appendix Table L1. Additional research was completed by Smith (2013) and Iverson (2013) to characterize lithology and grain size at the respective sites. The previous researcher's methodology was discussed in Appendix L.

Porosity

Smith (2013) estimated the median porosity for the schools in order to assess the relationship between porosity and resistivity values at both sites and to determine if there was a significant resistivity response to changes in porosity. Researchers found that changes in resistivity were present between background and drainfield locations while porosity values remained similar (Smith, 2013). Therefore, porosity changes across the sites were not a dominant factor influencing the significant differences in resistivity observed at the sites. The methodology and results for the Smith (2013) porosity analysis was provided in Appendices L (Methodology: Porosity).

In the current study, total porosity and specific yield were estimated at all sites using soil series data collected from the NRCS webpage. The total porosity and specific yield values characteristic of the dominant soil types at each site were listed in Appendix Table L1and L2. The methodology for total porosity and specific yield estimation is also listed in Appendix L (Methodology: Porosity).

Hydrology Characteristics

Smith (2013) assessed hydraulic conductivity as a possible control on resistivity at the schools. Researchers found that the hydraulic conductivity values at each site exhibited a weak relationship with corresponding resistivity values (Smith, 2013). The methodology for hydraulic conductivity estimation by Iverson (2013) and Smith (2013) was provided in Appendix M.

The current research used estimated K_{sat} values taken from the USDA NRCS Web Soil Survey Soil Report (2014) for the dominant soil series at each site (Appendix Table L1). The K_{sat} estimates ranged from 0.35-1.2 m/day for all sites except the Residential 100 drainfield area located within the Lynchburg Series. The Residential 100 drainfield area was characterized by K_{sat} values that ranged from 0.12-1.2 m/day and were described by the report as "somewhat poorly drained" (NRCS, 2015).

Groundwater flow direction and hydraulic gradient were estimated at the education center using the three point method (Heath, 1983). The same methodology was used by Smith (2013) for the schools and by Iverson (2013) for Residential 100-400 sites (Heath, 1983). Relative ground surface elevations were surveyed at each piezometer using a rotating AUTOLASER 300 level (Iverson, 2013 and Smith, 2013). Relative piezometer elevations were subtracted from the North American Datum of 1983 (NAD83) to obtain ground surface elevation estimates (Iverson, 2013 and Smith, 2013). Hydraulic head elevations were recorded in meters above mean sea level (mamsl). Hydraulic head values for piezometers on all sample dates were listed in Appendix Table E1. The average hydraulic head values for piezometers throughout the study were listed in Appendix Table E3. In Appendix O1, hydraulic gradient maps were generated using the averaged hydraulic head values in Appendix Table E3.

Groundwater discharge for the estimated wastewater plume area was calculated using Darcy's Law in equation 1 below.

$$Q = K * A * \frac{dh}{l} \qquad \text{(Eq. 1)}$$

Where Q = discharge (m^3/day), K = hydraulic conductivity (m/day); A = cross-sectional area (m^2); dh/dl = hydraulic gradient: dh = change in head (m); l = distance between piezometers (m). The discharge values were estimated using the cross-sectional area (A) calculated from the CCR survey transects: Figure 15 (high school) and Appendix Figure I1 (elementary school). The CCR surveys were used to calculate the depth and width of the wastewater plume characterized by resistivity values less than or equal to 250 Ω.m at sites in which a wastewater plume was identified below the drainfield (Appendix Table U1). For these discharge calculations the hydraulic conductivity and hydraulic gradient values were collected only from the drainfield piezometers shown on the figures and the water levels collected on the CCR survey dates (Appendix U). Appendix Table U1 shows the parameters and values used for the Darcy's Law discharge estimates calculated using the CCR surveys.

The discharge values were also estimated by calculating the cross-sectional area (A) using the OWS permit drainfield width and the drainfield piezometer depths with corresponding water quality data characteristic of wastewater inputs. The water quality data were reviewed for all sample dates to achieve a general cross-sectional area for the entire study period. Only the drainfield piezometer hydraulic conductivity and hydraulic gradient values were used to calculate the OWS groundwater discharge. The hydraulic gradient values were calculated using water level averages for the entire study period for all drainfield piezometers. Appendix Table U2 shows the parameters and values used for the Darcy's Law discharge estimates.

Groundwater velocity was estimated at each site using equation 2 in order to approximate groundwater travel times (Heath, 1983).

$$v = \frac{K * dh}{\mathrm{n} * \mathrm{l}} \qquad \text{(Eq. 2)}$$

Where v is average linear groundwater velocity (m/day), K is hydraulic conductivity (m/day), n is the porosity, and dh/l is the hydraulic gradient in m/m. Groundwater velocity was calculated using K estimates from Smith (2013), Iverson (2013), Humphrey et al. (2013), and the USDA Craven County Soil Survey (1989), Pitt County Soil Survey (1974), Web Soil Survey (2014).

The porosity estimates were collected from the Soil Survey data. Groundwater velocity values and parameters for each site are listed in Appendix Table U3.

Ground and Surface Water Monitoring

To address objectives 1 and 2 ground and surface water monitoring was completed during the study. Bi-monthly water quality analysis was conducted in the field from June 2012-June 2013 at all sites using a calibrated *Solinst* TLC meter to measure depth to groundwater and specific conductivity (Appendix Table C1). The *Solinst* TLC displays conductivity which has been standardized to 25°C. Additional data were collected using a calibrated *YSI-556 Multi-Probe Meter* to measure specific conductivity (µS/cm), temperature (°C), DO (mg/L), pH, and a calibrated *YSI-ProPlus* to measure pH, NO3-N (mg/L), Cl (mg/L), and NH4-N (mg/L). The sites and corresponding piezometers, water quality values, and data collection methods used are listed in Appendix E. The average water level on survey dates are provided in Appendix V.

Wastewater effluent, groundwater and surface water samples were collected at the schools, Residential 100, and the education center for laboratory analysis in conjunction with CCR and GPR surveys. Water quality samples and analysis in the field were completed once at Residential 200, 300, and 400 sites in conjunction with CCR and GPR surveys in order to provide supplemental data. Wastewater effluent samples were collected from either the outlet compartment of the septic tank (Residential sites, the education center, and high school) or from a distribution box (elementary school). Surface water samples were collected from sites in which adjacent water bodies were present (the schools and Residential 100). Prior to sampling, piezometers were purged using disposable bailers and allowed to recharge for sample collection. Samples were stored in 250 ml bottles. The samples were directly transported to the Department of Biology Central Environmental Research Lab (CERL), centrifuged, and then vacuum filtered through ashed 1.5 micron filters. Samples were analyzed within 24 hours of filtering or frozen until analysis. Samples were analyzed using a Westco Scientific Instruments Incorporated automated SmartChem 200 Discrete Wet Chemistry Analyzer in accordance with EPA approved methods (Appendix Table C2). The parameters analyzed included: chloride (Cl), ammonium (NH_4-N), nitrate and nitrite (NO_3-N+NO_2), phosphate (PO_4-P) and dissolved kjeldahl nitrogen (DKN). Total dissolved nitrogen (TDN) was calculated by adding dissolved kjeldahl nitrogen (DKN) and NO_3-N+NO_2; the values are listed in Appendix Table D and assessed in Appendix Table N.

Geophysical Surveys

To address objectives 1 and 2 CCR survey resistivity values were conducted on water quality sampling and survey dates listed in Appendix Table C1. To address objective 3 ground penetrating radar surveys were conducted on the same dates in order to identify OWS components (Appendix C1).

The locations and grid lengths of the 2D and 3D geophysical survey transects were determined based on maneuverability and presence of obstacles at each site, proximity to and location of the OWS, and groundwater flow direction. 3D surveys were conducted in order to obtain horizontal and vertical characterizations of the subsurface and were conducted along a zig-zag pathway. The locations of the 3D and 2D transects for each site are shown in Appendix Figures H1-H7. 2D transects were conducted in order to obtain a cross-sectional view of the subsurface. Additional CCR survey transects were conducted in September in order to gain additional resistivity data at the schools. Previous geophysical surveys had not been conducted at the Residential 100 or the education center. Residential 200, 300, and 400 were only surveyed once in order to provide supplemental data for objectives 1 and 2.

Capacitively Coupled Resistivity (CCR)

A capacitively coupled resistivity mapper, OhmMapper, was used to collect apparent resistivity measurements of the subsurface at each of the sites within, up, and down gradient of the drain fields. The OhmMapper uses a dipole-dipole configuration consisting of capacitively coupled electrodes (Figure 7). The OhmMapper array is towed along the ground surface. The transmitter releases a low frequency alternating current (AC) signal of approximately 16.5 kHz that is transmitted into the dipole cable and then flows into the ground (Geometrics, 2001). The receiver dipole cable picks up the signal, which is measured and decoded by the receiver, converted to an optical digital signal and transmitted through the fiber optic wand (isolator cable) (Figure 7). The signal is then reconverted to an electrical signal and sent up the tow cable to the console where a converter amplifies the signal to a pseudo-RS232 signal level that is read by the console (Geometrics, 2001). Once the survey is complete the data can be downloaded from the console to the PC (Geometrics, 2001) (Figure 7).

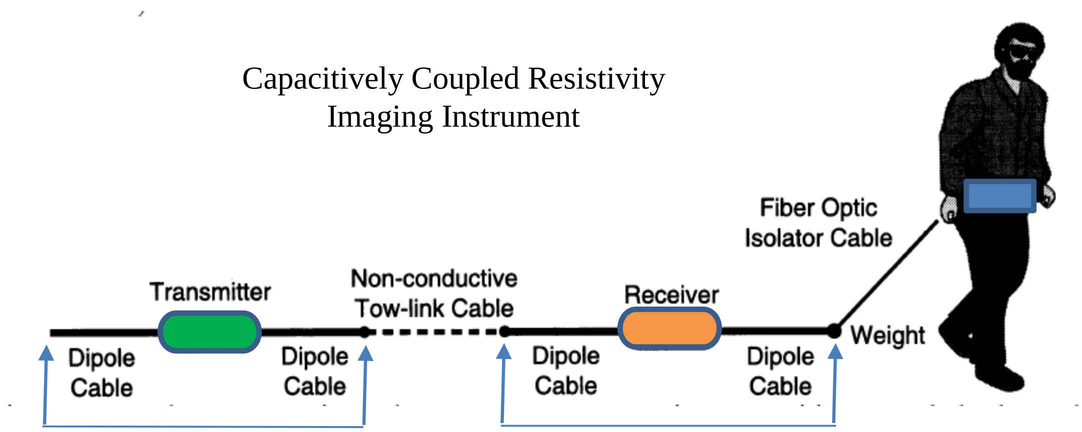

Figure 7. The OhmMapper array with the transmitter in green, receiver in orange and console in blue (modified from Geometrics, 2013). In the current study, there are two, 2.5m, individual dipole cables used for the receiver and two, 2.5m, dipole cables used for the transmitter (these are shown by the blue connected arrows) resulting in 5m dipoles; these dipole lengths were used for the majority of the study.

Ohm's Law (Eq. 3) is the fundamental equation used to calculate a material's resistance to current flow. The amount of potential difference required for a given current (I =current) is directly proportional to the resistance as seen in Equation 3.

$$R = \frac{\mathrm{V}}{\mathrm{I}} \qquad \text{(Eq. 3)}$$

Where R = resistance (Ω), V = voltage (volts), and I = current (amps) in Equation 3 (Geometrics 2001). Resistance is not equal to resistivity. Resistance depends on the material's resistivity and the cross-sectional area and length of the material the current is flowing through as seen in the Equation 4 below.

$$\rho = \mathrm{R}\frac{\mathrm{a}}{\mathrm{l}} \qquad \text{(Eq. 4)}$$

Where ρ = resistivity (Ω.m), R = resistance (Ω), I = current (amps), a = cross-sectional area (m^2), and l=length (m) Equation 4 (Burger, 1992). During data collection the signal stored in the OhmMapper console is the apparent resistivity.

$$\rho_a = k * R \tag{Eq. 5}$$

Where ρ_a = apparent resistivity (Ω.m), R=resistance (Ω), k = geometric factor in Equation 5 (Loke, 2000). The geometric factor is based on dipole length, dipole type, and transmitter-receiver separation and as seen in equation 5 is used to convert the raw resistance value to an apparent resistivity of the material between the points at which the current is injected into the material and the point at which it is measured (Geometrics, 2001).

The dipole cable lengths and the length of non-conductive tow link-cable can be varied in order to change the depth at which apparent resistivity readings are collected (Figure 7) (Geometrics, 2001). In the current study, the lengths of the non-conductive tow link-cables used were 2.5, 5, 10 and 20 m. When the length of the non-conductive tow link-cable is increased the target depths are increased. The non-conductive tow link-cables were generally used with 5m dipole cables surveys to generate an investigation profile of 0 – 7 mbgs (Figure 7). At sites with very shallow water tables (≤1 m) when the surface materials were more conductive, in some cases 5 m dipoles would not reliably image the deeper materials, therefore 10 m dipoles were used. The dates and transects in which the 10 m long dipoles were used are marked by an asterisk in Appendix C1. CCR survey collection dates, transect lengths, 3D grid parameters, and spacing between grid lines are listed in Appendix C1, C3, and C4.

Apparent resistivity data collected from the surveys were inversely modeled using Res2Dinv (v.3.55) and Res3Dinv (v.2.15) (Geotomo Software, 2010, 2011) to obtain an estimate of the actual resistivity of the subsurface and to aid in data presentation. Actual resistivity values were obtained from .xyz data sheets output by Res2Dinv. Resistivity values to compare with groundwater quality data were only collected along transects and were measured in units of Ω.m. Actual resistivity values were selected from a YZ location on a CCR transect. The Y location was measured as horizontal distance from the start of the transect to any piezometer that was less than or equal to 5 m from a transect's location. The Z value was the selected piezometer's depth to the bottom of the screen (mbgs). All resistivity values were selected in this manner unless otherwise noted. The Z and Y values were listed in Appendix Table P1. The resistivity values along with corresponding groundwater specific conductivity values and supplemental data were organized based on the source piezometer's location within background, drainfield, and downgradient areas at each site (Appendix Table F1and F2). Due to time constraints only downgradient resistivity data were collected at Residential 200. Downgradient resistivity values were not collected from the elementary school downgradient piezometers because the piezometers were located within the riparian buffer. The high density of trees and vegetation located within the riparian buffer prevented site access for geophysical surveying and were not easily attainable with the OhmMapper. At the education center, the resistivity value for background piezometer 1 was extrapolated from Transect 1 due to the presence of obstacles (Appendix Table P1). The output .xyz data points from Res2Dinv were contoured in Surfer to better visualize changes in resistivity values. The Surfer nearest neighbor interpolation method was used to estimate resistivity values between grid nodes (.xyz points). This method was used to contour 2D transect sections and 3D slices. The depth of the 3D slice was determined based on the average water level (mbgs) for each site. The contoured 2D sections were overlaid with the locations of piezometers and corresponding resistivity and groundwater specific conductivity values collected at each piezometer on the 2D transects.

Archie's Law was used to estimate the pore water resistivity using the bulk resistivity and a formation factor (F) (Equation 6-8) (Archie, 1942 and Urish, 1983).

$$F = \alpha n^{-m} \qquad \text{(Eq. 6)}$$

Equation 6 was used to determine the formation factor (F); α is a constant, n is porosity, and m is the cementation constant; the values characteristic of sandy soils were α=1 and m=1.3 (Winsaur et al. 1952). Pore water resistivity was calculated using the equation by Urish 1983. The porosity values (n) were selected from the soil series total porosity values characteristic of each study site (Appendix Table L2).

$$F = \frac{p_b}{p_w} \qquad \text{(Eq. 7)}$$

$$p_w = \frac{p_b}{F} \qquad \text{(Eq. 8)}$$

In equation 7 and 8, the p_w is the pore water resistivity, p_b is bulk resistivity and F is the formation factor. The calculated formation factors (F) are listed in Appendix Table L2. Site specific formation factors were calculated to better assess the site specific relationships between calculated pore water specific conductivity and bulk resistivity values as well as resistivity and groundwater specific conductivity values. In equation 9, the estimated pore water resistivity value was used to estimate the pore water specific conductivity values (p_c) by converting the pore water resistivity (Ω.m) to specific conductivity (µS/cm).

$$p_c = \frac{1000}{p_w} \qquad \text{(Eq. 9)}$$

The pore water resistivity, calculated using equation 8, was converted to pore water specific conductivity using equation 9. The calculated pore water specific conductivity values were coupled with the resistivity values collected from the Res2D inversion software CCR survey to generate a theoretical regression equation. The theoretical equations for objective 1 are listed in Appendix Table Q1. The objective 2 theoretical equations are listed on the corresponding scatter plots for each site (Appendix R). The pore water resistivity values and calculated pore water specific conductivity values are listed in Appendix T. The theoretical equation may provide an estimate of possible pore water resistivity and groundwater specific conductivity values at the sites with a strong relationship between measured resistivity and groundwater specific conductivity.

Ground Penetrating Radar (GPR)

GPR surveys were conducted at sites with large OWS (the schools) and sites with small OWS (the education center, and Residential 100). A Geophysical Survey Systems Inc. (GSSI), SIR-2000 system, with a 200 MHz antenna was used to image to depths of approximately 1-12 mbgs at the schools in order to identify OWS system components (Smith, 2013). The current study utilized similar methods and approach as Smith (2013). GPR data were collected in continuous monostatic mode, using a calibrated survey wheel at a scan rate of 20 scans/m, and a sampling rate of 1024 samples/scan, with a sampling window of 200 ns. 2D and 3D transects were conducted to locate OWS components at each site. The 3D grid pattern with 1 or 2 m line spacing was used in order to locate the drainfield trenches and other OWS components present within the survey area. 2D transects were conducted to image a cross-sectional view of the subsurface and drainfield trenches at each site. When collecting data, high amplitude hyperbolic reflections, shown in real time on the GPR console, were matched with locations of the drainfield trenches determined using a tile drain probe and the site's OWS permit. The information for transects and 3D surveys including length, ID, and grid spacing were listed in Appendix Table C1, C2 and C4. Map view locations of the 3D survey area and 2D transects at each site are shown in Appendix H1-H7.

Data were processed using Radan v. 6.6 software (copyright GSSI), which allows for 2-D and 3-D visualization. The GPR data were processed in Radan using infrastructure identification for a 200 MHz antenna, band-pass filtering (FIR filter) and then Kirchhoff constant velocity migration (Radan v. 6.6). The addition of the infrastructure identification processing step was not used in Smith (2013). The processing step was recommended in Radan v. 6.6 to help improve visibility of the finite features on the radar record. The infrastructure identification was used to remove the surface delay and a horizontal filter that was part of the infrastructure identification step was used to remove signal noise (Radan v. 6.6). The band-pass filtering (FIR filter) was used to filter out horizontal and vertical signal noise (Radan v. 6.6). The GPR emits radar waves using a beamwidth pattern, which can result in hyperbolic diffractions and dipping layers (Radan v. 6.6). The hyperbolic reflectors were characteristic of objects of finite dimensions, such as drainfield trenches, and occurred on the radar record as the antenna detects the object from far off and then moves over and past it (Radan v. 6.6). The Kirchhoff constant velocity migration was used to correct for hyperbolic reflections present (Radan v. 6.6). To aid in interpretation, the GPR data were enhanced by selecting color table 25 and a gain of 8 to increase the intensity of the color table and make the high amplitude reflections associated with drainfield trenches visible (Radan v. 6.6). The color table represented amplitude and amplitude polarity. The colors ranged from red (positive/normal amplitude) to white (zero amplitude) to blue (negative/reverse amplitude) (Radan v. 6.6). The intensity of the color ranging from dark red/blue to lighter red/blue indicated an increase in amplitude from lighter (faded) colors (low amplitudes) to darker, intense colors (higher amplitude values). The intensity of the reflection color was proportional to the dielectric contrast between two materials. The greater the contrast the greater the intensity of the color (the color was darker) (Radan v. 6.6).

Statistical Analysis and Comparisons

Non-parametric Mann-Whitney tests were used to compare data sets and determine if the 2 compared data sets were significantly different. All Mann-Whitney tests were completed using Minitab v. 16.1. The compared datasets were considered significantly different if the resulting p-value was less than 0.05 (Minitab v.16.1).

For objective 1, background data sets were compared with the drainfield data sets. The resistivity and groundwater specific conductivity values used in the comparisons are listed in Appendix Table F1 (columns labeled: "Specific Conductivity (μS/cm)" and "Ω.m Selected at Screened Interval"). The drainfield datasets were expected to be significantly different from the background datasets due to the wastewater inputs expected within the drainfield area.

For objective 2, downgradient data sets were compared with background data sets to determine if there was a significant difference between downgradient distributions and drainfield distributions. The downgradient data sets were also compared with drainfield data sets to determine if there was a significant difference between downgradient distributions and background distributions. The resistivity and groundwater specific conductivity values used in the comparisons are listed in Appendix F2 columns labeled "Ω.m Selected at Screened Interval" and "Specific Conductivity (µS/cm)".

Boxplots were used to aid in visualization of data distribution and range, median values and outliers for objectives 1 and 2. The boxplots were generated in Minitab v. 16.1. using the default quartile settings. Each boxplot was divided into 4 equal parts (quartiles or Q). On a boxplot the interquartile range box shows the distance from first quartile (Q1) and third quartile (Q3). On an interquartile range box the bottom line marks the value for the first quartile (Q1) where 25% of the data is less than or equal to the value. The middle line (median: Q2) marks where 50% of the data is equal to or less than the median value. The top line (Q3) marks where 75% of the data is equal to or less than the top line value. The whiskers are the lines that extend from the top and bottom of the interquartile box. The top whisker upper limit of the data set, excluding outliers, is equal to Q3 + 1.5 (Q3 - Q1); the bottom whisker is equal to Q1 - 1.5 (Q3 - Q1). The resistivity and groundwater specific conductivity values used for objective 1 are listed in Appendix Table F1 and the resistivity and groundwater specific conductivity values used in objective 2 are listed in Appendix Table F2. Median values were used for comparison instead of mean in order to decrease the influence/weight of outlier values.

Log (resistivity) vs. groundwater specific conductivity regression analysis (Appendices Q and R) were used to assess the CCR survey resistivity response to groundwater specific conductivity. The Log of the resistivity values was taken to aid in data presentation and visualization of the data set distribution. The schools' resistivity datasets had a significant range that was best visualized using the semi-log scale. Previous research by Smith (2013) utilized Log (resistivity) to assess the relationship between resistivity and groundwater specific conductivity.

All comparisons and analysis were completed for the pooled data sets and then for individual data sets. The objective 1 data sets included background and drainfield values. The objective 1 pooled data set sites consisted of the elementary school, high school, education center, Residential 100 and supplemental Residential 300 and 400. The objective 2 data sets included background, drainfield, and downgradient values. The objective 2 pooled data set sites consisted of the high school, education center, Residential 100 and supplemental Residential 200.

Smith (2013) found that the resistivity values collected from drainfield piezometers less than 250 Ω.m may be influenced by wastewater inputs. The current study utilized a 250 Ω.m reference line on scatter plots to visualize the differences in resistivity and groundwater specific conductivity value trends present at the schools. The 250 Ω.m reference line was used to provide a general method of grouping resistivity values. The ranges of the data and individual data values are provided in Appendix E and objectives 1 and 2.

Results

Objective 1: Determine if CCR surveys could detect resistivity responses to increases in groundwater specific conductivity associated with wastewater inputs to drainfields across a range of systems

Table 4 summarizes the Mann-Whitney comparison p-values, sample numbers, and median values calculated for resistivity and groundwater specific conductivity values collected from background (BG) and drainfield (DF) locations. The pooled data comparisons between background and drainfield data sets had p-values < 0.05, and the contrast between background and drainfield groundwater specific conductivity medians was 166 µS/cm (Table 4). The pooled data Log resistivity values were inversely related to the corresponding groundwater specific conductivity values (Appendix Q). The pooled data was divided into 4 focus study sites. The 4 focus study sites had elevated groundwater specific conductivity in the drainfields relative to background groundwater (Table 4).

Table 4. Pooled and individual site groundwater specific conductivity or GW SC (µS/cm) and resistivity (Ω.m) collected from background (BG) and drainfield (DF) locations. The R^2 values were collected from BG and DF Log resistivity vs. groundwater specific conductivity regression analysis. Individual site R^2 values were determined for Residential 300 (R^2=0.63) and 400 (R^2=0.38).

Site	Location	Sample Number	Median Groundwater Specific Conductivity (µS/cm)	GW SC p-value	Median Resistivity (Ω.m)	Resistivity p-value	R^2
Pooled Data	BG	36	113	0.0000	466	0.0000	0.35
	DF	81	279		102		
Elementary School	BG	8	112	0.0001	1714	0.0001	0.60
	DF	17	615		112		
High School	BG	13	79	0.0000	1283	0.0000	0.72
	DF	29	363		81		
Education Center	BG	7	128	0.5728	178	0.8325	0.04
	DF	15	130		161		
Residential 100	BG	6	198	0.3429	122	0.5362	0.03
	DF	14	244		96		
Residential 300 and 400	BG	2	117	1.0000	433	0.2433	-
	DF	6	107		93		

The high school and elementary school groundwater specific conductivity and resistivity data sets were significantly different across background and drainfield locations ($p < 0.05$) (Table 4 and Figure 8). The wastewater inputs were expected to be highest below the drainfield at the high school and elementary school due to the large OWS and maximum design flows (Table 3). Subsequently, the contrasts between background and drainfield medians were highest at the elementary school (503 µS/cm, 1,602 Ω.m) and the high school (284 µS/cm, 1,202 Ω.m)

(Table 4 and Appendix Q). The schools also had the highest R^2 values calculated from Log resistivity vs groundwater specific conductivity regression analysis (Table 4).

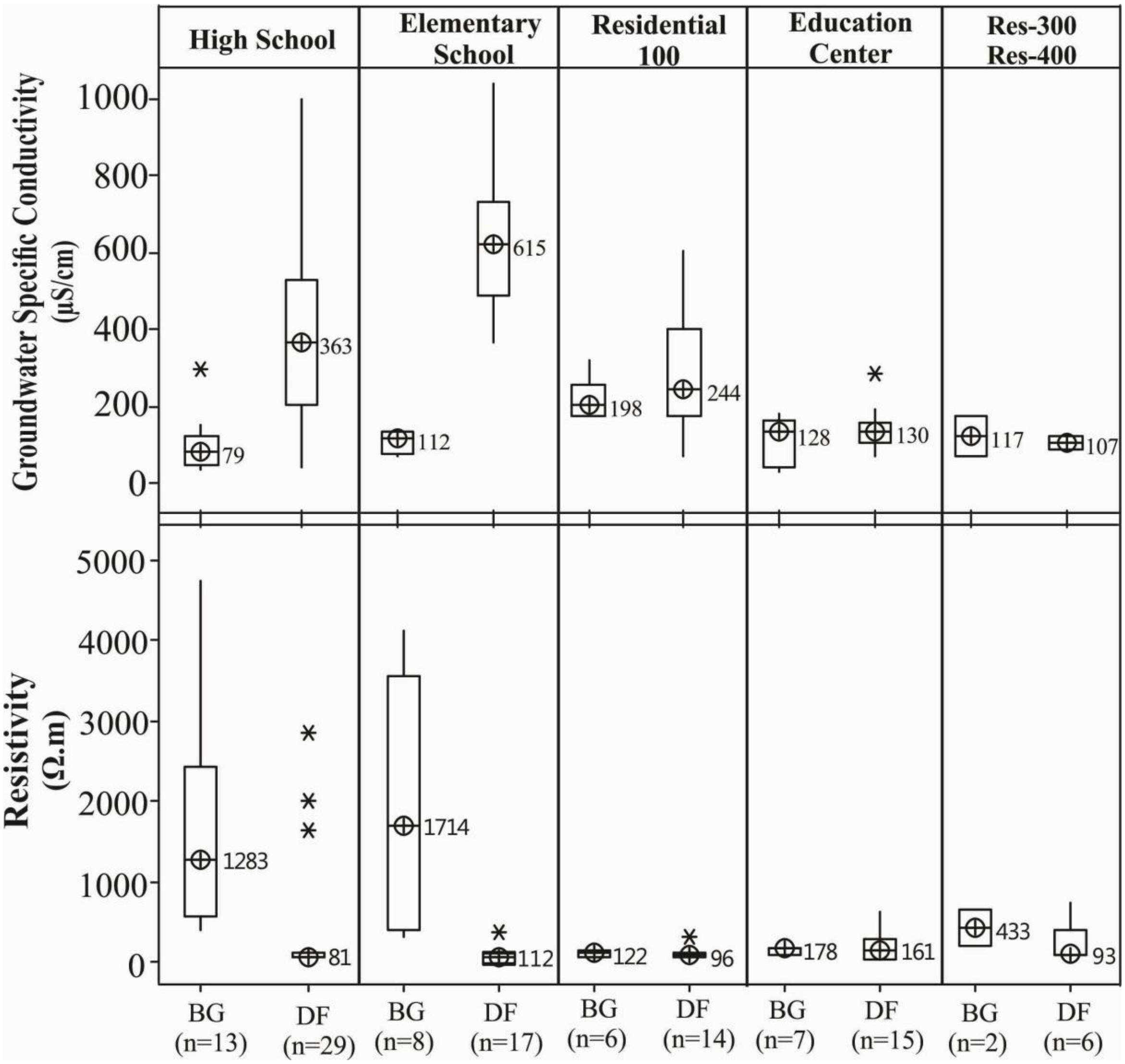

Figure 8. The top boxplot shows groundwater specific conductivity (µS/cm) values collected from background (BG) and drainfield (DF) piezometers and the bottom box plot shows resistivity values (Ω.m) collected from corresponding background and drainfield locations.

Lower wastewater inputs were expected below the drainfield field at the sites with small OWS and lower maximum design flows (Table 3). The residential sites and education center were characterized by low contrasts between background and drainfield groundwater specific conductivity medians (< 50 µS/cm) and p-values > 0.05 (Table 4, Figure 8, and Appendix Figure Q). The residential and education centers had R^2 values less than the high school and elementary school R^2 values (Table 4). Individual site comparisons of resistivity vs groundwater specific conductivity were used to identify and the characterize resistivity responses to changes in groundwater specific conductivity across background and drainfield locations.

Sites with Large OWS (High School and Elementary School Sites)

In Figure 9, the regression analysis of Log resistivity versus groundwater specific conductivity supported an inverse relationship between the data sets. The elementary school background was characterized by resistivity values greater than 250 Ω.m and corresponding groundwater specific conductivity values less than 200 µS/cm (Figure 9). The elementary school drainfield resistivity values were less than 250 Ω.m and corresponding groundwater specific conductivity values were greater than 200 µS/cm (excluding piezometer 4 (11/19/2012)) (Figure 9). The resistivity values less than 250 Ω.m beneath the elementary school drainfield were characteristic of wastewater influence.

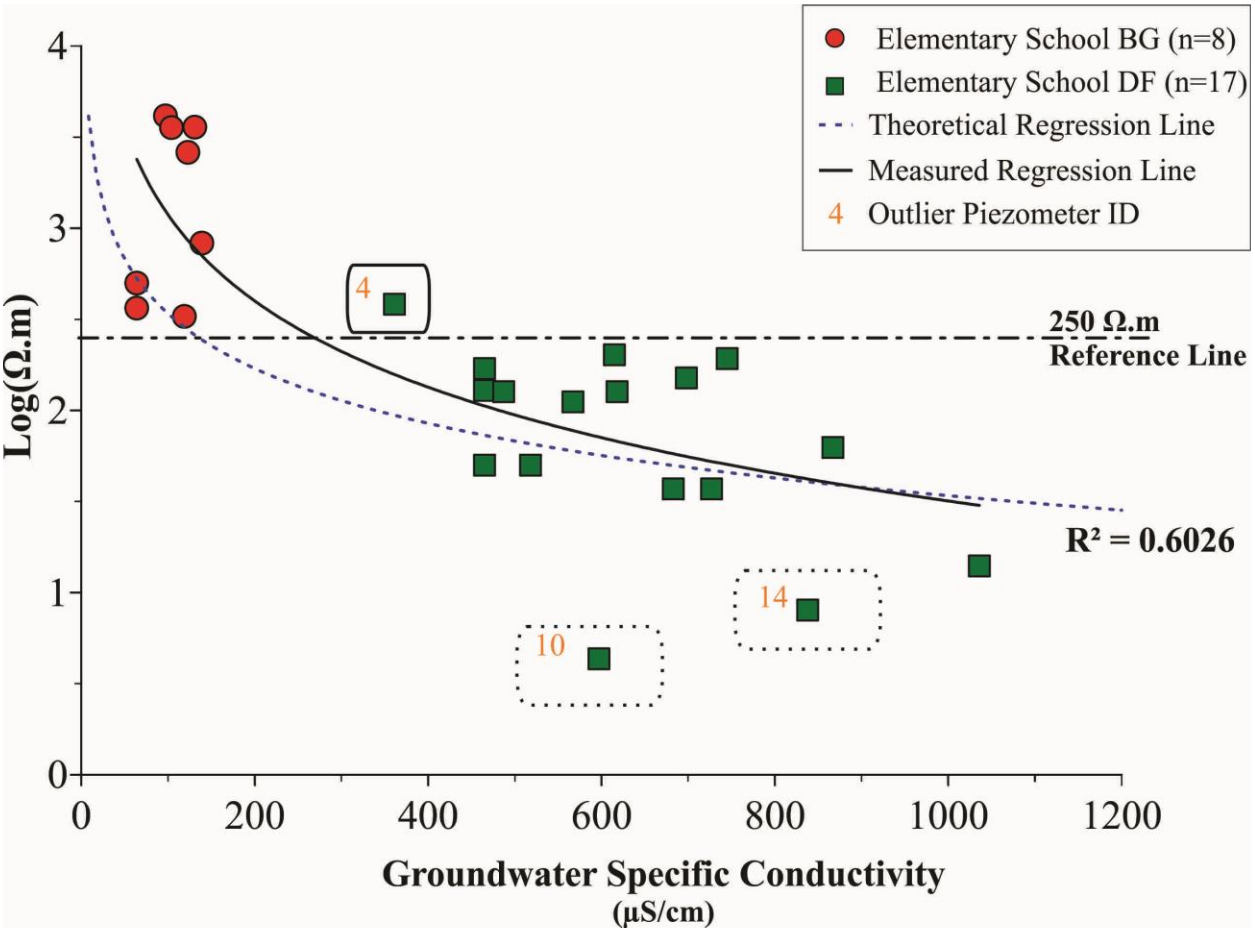

Figure 9. Scatterplot of the elementary school background (BG, circles) and drainfield (DF, squares) groundwater specific conductivity and Log resistivity data. The measured regression line (solid black line) and theoretical regression line (dashed purple line) are shown (Appendix Table T1, and Table Q1). A dot-dashed, black reference line was set at 250 Ω.m. The solid black line circle shows outliers with resistivity values greater than 250 Ω.m and the dashed black line circle shows outliers with resistivity values less than 250 Ω.m. Outlier values are listed in Appendix Table G1.

In Figure 9, the outlier, drainfield piezometer 4 (11/19/2012, solid black line) had an elevated groundwater specific conductivity value (greater than 200 µS/cm) and an elevated corresponding resistivity value (greater than 250 Ω.m). Outlier piezometers 14 and 10 collected on 9/7/2012 (dashed black line) had elevated groundwater specific conductivity (greater than 200 µS/cm) and low resistivity values (less than 250 Ω.m) characteristic of wastewater influence (Figure 9).

The high school regression analysis shown in Figure 10 was indicative of an inverse relationship between Log resistivity and groundwater specific conductivity. All of the high school background resistivity values were greater than 250 Ω.m and had corresponding groundwater specific conductivity values less than 200 µS/cm excluding background piezometer 1s (red rectangle) (Figure 10). In Figure 10, piezometer 1s (red rectangle) had a resistivity value ≥250 Ω.m and a groundwater specific conductivity value ≥200 µS/cm.

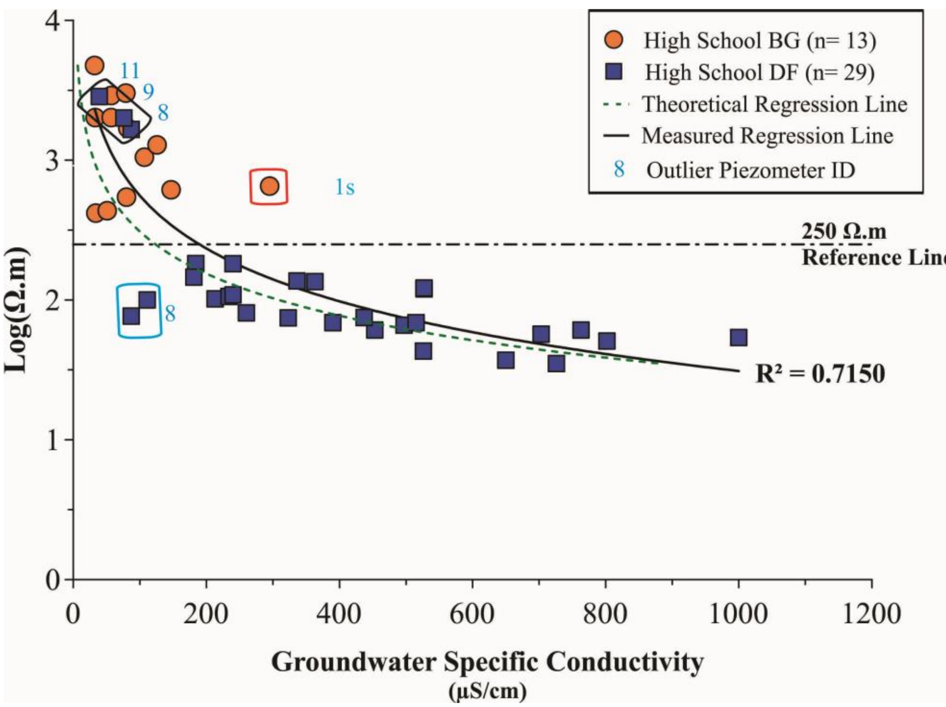

Figure 10. Scatterplot of the high school background (BG, circles) and drainfield (DF, squares) groundwater specific conductivity and Log resistivity data. The measured regression line (solid black line) and the theoretical regression line (dashed purple line) are shown (Appendix Table T1, and Table Q1). A dot-dashed, black reference line was set at 250 Ω.m. The rectangles identify outliers. The light blue numbers outside the rectangles are the piezometer ID numbers. The outlier values are provided in Appendix Table G1.

The majority of the high school drainfield resistivity values were less than 250 Ω.m and had corresponding groundwater specific conductivity values greater than 200 µS/cm, excluding 3 drainfield outliers. In Figures 9 and 10, the measured and theoretical regression analysis showed similar resistivity responses to changes in groundwater specific conductivity at the high school and elementary school. The theoretical regression analysis incorporated pore water specific conductivity values calculated using site specific formation factors (specified in Methods).

Sites with Small OWS (Residential and Education Center Sites)

The education center and Residential 100 were the main focus sites with small OWS. The education center OWS was installed in 2012 and the system usage was expected to be sporadic. The contrast between the median background and drainfield groundwater specific conductivity values was minimal (2 µS/cm), as was the contrast between the median background and drainfield resistivity values was 17 Ω.m (Table 4). All of the background and drainfield piezometers had groundwater specific conductivity values less than 200 µS/cm, except drainfield piezometer 2s on 9/4/2012 (284 µS/cm) (Appendix Q). The average drainfield groundwater specific conductivity was 132 ± 54 µS/cm (n=15) and average background groundwater specific conductivity was 107 ± 54 µS/cm (n=7). The resistivity values ranged 29-628 Ω.m and the drainfield resistivity values ranged from 46-628 Ω.m. The highest resistivity values were collected on the last survey date (4/17/2013) (Figure 11).

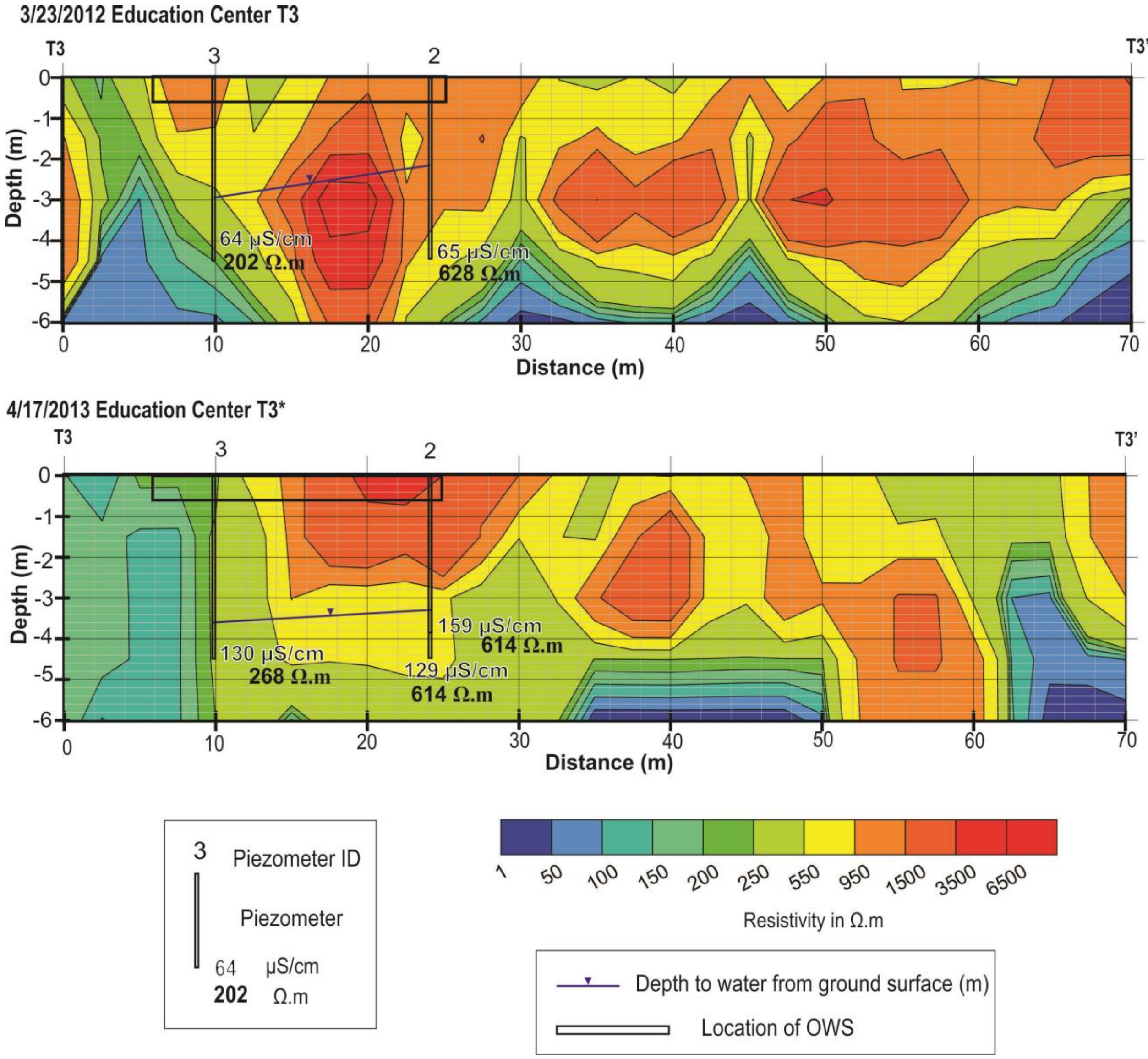

Figure 11. Resistivity cross-section of T3 at the education center on 3/23/2012 and 4/17/2013*. T3 was collected parallel to the drainfield trench orientation (Appendix Figure H3). Groundwater specific conductivity (µS/cm) values are listed near the bottom of or adjacent to the screened interval of piezometers (black rectangle). Corresponding resistivity (Ω.m) values are listed in bold black below the µS/cm values. On 4/17/2013 10 m dipoles were used.

In Figure 11, CCR transects were used to provide a visual of the subsurface estimated resistivity values collected on the first and last survey dates. In Figure 11, the drainfield piezometers were characterized by resistivity values greater than 200 Ω.m and groundwater specific conductivity values less than 200 µS/cm on the first and last survey dates (3/23/2012 and 4/17/2013). In Figure 11, the low resistivity zone located within the first 10 m on T3 was present on all survey dates and was visible on transects utilized in objective 2.

The education center median and mean TDN values for background, drainfield, and downgradient piezometers collected on survey dates were less than 5 mg/L (Appendix N). Background TDN values ranged from 0.53-4.22 mg/L and drainfield TDN values ranged from 0.81-7.53. The contrast between the median background and drainfield TDN values was 2.99 mg/L (Appendix N). The groundwater specific conductivity contrast between background and drainfield areas were not significant enough to result in a resistivity response beneath the education center drainfield.

Residential 100 had background and drainfield groundwater specific conductivity and resistivity data sets that were not significantly different ($p > 0.05$). Residential 100 had the highest median background groundwater specific conductivity value (198 µS/cm) (Table 4 and Figure 8). The median background and drainfield groundwater specific conductivity contrast was 46 µS/cm, and the median background and drainfield resistivity contrast was 26 Ω.m (Table 4). The background and drainfield resistivity values ranged from 19-174 Ω.m (< 200 Ω.m). The background groundwater specific conductivity values ranged from 171-316 µS/cm. The Residential 100 drainfield groundwater specific conductivity range was 69-600 µS/cm (Appendix Q). The 3 highest groundwater specific conductivity values were collected from drainfield piezometer 110s and exceeded 400 µS/cm. The drainfield piezometer 110s was located along the perimeter of the drainfield within the flow path of the OWS (Figure 6). On all survey dates the drainfield piezometer 110s was characterized by groundwater specific conductivity values > 400 µS/cm and resistivity ranged from 73-119 µS/cm (< 200 µS/cm)

(Appendix Q). Additionally, piezometer 110s had the highest average TDN (20.28 ± 4.26 mg/L; n=3) and median TDN (19.08 mg/L; n=3) relative to the remaining Residential 100 drainfield piezometer average and median TDN values. Piezometer 110s was characterized by elevated groundwater TDN (20.27 ± 4.26) and specific conductivity (545 ± 45.6 µS/cm; n=3) values in addition to low average resistivity values (97.5 ± 18.9 Ω.m; n=3) that indicated wastewater influence was detected at the piezometer. Transects were collected to better illustrate the spatial variability of resistivity values across the Residential 100 drainfield and background areas (Figure 12).

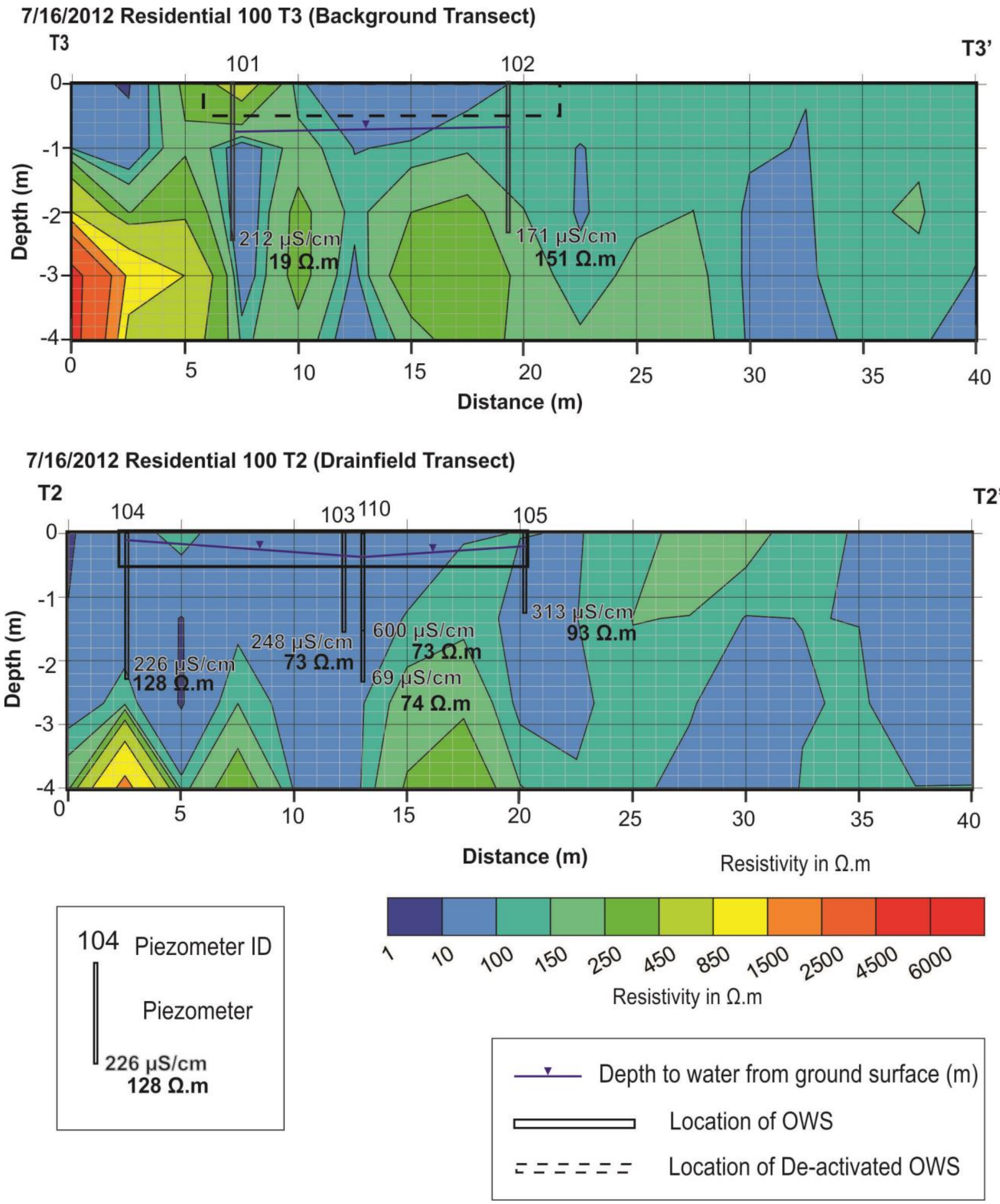

Figure 12. Resistivity cross-sections of Residential 100 T3 (Background) and T2 (Drainfield) collected on 7/16/2012 (Index Map: Appendix Figure H4). Groundwater specific conductivity (µS/cm) values are listed adjacent to the bottom of the screened interval of piezometers (black vertical rectangle). Corresponding resistivity (Ω.m) values are listed below µS/cm values in a bold black font.

The piezometers in both T3 (Background) and T2 (Drainfield) had resistivity values ≤250 Ω.m across background and drainfield locations (Figure 12). In Figure 12, T3 (Background), the background piezometer resistivity values were 19 and 151 Ω.m and the groundwater specific conductivity values were 212 and 171 µS/cm, respectively. In Figure 12, T2 (Drainfield), the resistivity values collected from drainfield piezometers (n=3) ranged from 73-128 Ω.m with corresponding groundwater specific conductivity values that ranged from 226-313 µS/cm, excluding piezometers 110s and 110d (n=2). Nested piezometers 110s and 110d, were located less than 1 meter apart yet both had significantly different groundwater specific conductivity values and similar resistivity values (Figure 12 and Appendix Q). On 7/16/2012, piezometers 110s and 110d groundwater specific conductivity values were 600 µS/cm (110s) and 69 µS/cm (110d) respectively, and the corresponding resistivity values were 73 Ω.m (110s) and 74 Ω.m (110d) (Figure 12). The elevated groundwater specific conductivity values (≥ 400 µS/cm) characteristic of 110s were not evident in 110d on all of the sample dates (Figure 12 and Appendix Figure Q). The piezometer 110s was screened at approximately 0.75-1.6 mbgs. The average water table depth collected from piezometers at the site was 0.5 mbgs (n=20).

The supplemental study sites, Residential 300 and Residential 400 were surveyed and sampled once during the current study. The background and drainfield groundwater specific conductivity and resistivity values were assessed at Residential 300 and 400. The contrast between median background and drainfield groundwater specific conductivity values at Residential 300 and 400 was less than 20 µS/cm (Table 4)

Objective 1 Summary

In the current study, the wastewater inputs below the drainfield were expected to be highest within the drainfield at the sites with large OWS (the schools) relative to the sites with small OWS (Residential 100, 300, and 400 sites and the education center).

OWS wastewater influence below the drainfield was successfully detected using CCR surveys at the sites with large OWS. The elementary school and high school background and drainfield groundwater specific conductivity and resistivity distributions were significantly different ($p<0.05$) (Table 4). The schools' contrasts between the background and drainfield median groundwater specific conductivity values were > 280 µS/cm. Wastewater influence below the drainfield was characterized by measured resistivity ≤ 250 Ω.m at the sites with large OWS.

The background and drainfield groundwater specific conductivity data sets were not significantly different ($p> 0.05$), and the contrasts between the background and drainfield median groundwater specific conductivity values were less than 50 µS/cm at the sites with small OWS. The lower contrast in groundwater specific conductivity across background and drainfield locations did not result in a significant resistivity response below the drainfield.

Overall, the resistivity responses to changes in groundwater specific conductivity were most evident when the contrast between background and drainfield median groundwater specific conductivity data sets was greater than 200 µS/cm.

Objective 2: Determine if resistivity responses to wastewater inputs (and associated changes in groundwater specific conductivity) are detectable downgradient of the drainfield

Table 5 summarizes the Mann-Whitney comparison p-values, sample numbers, and median values calculated for resistivity and groundwater specific conductivity values collected from background (BG), drainfield (DF) and downgradient (DG) locations. The pooled data set consisted of values collected from the high school, Residential 100, education center and supplemental Residential 200 (Appendix R). In Table 5, the pooled, downgradient data set Mann-Whitney comparisons of groundwater specific conductivity had p-values < 0.01.

Table 5. Pooled and individual site groundwater specific conductivity (µS/cm) and resistivity (Ω.m) collected from background (BG), drainfield (DF), and downgradient (DG) locations. The Mann-Whitney comparison p-values less than 0.05 were listed in bold. The green dividers mark where the high school (HS) and education center (EC) downgradient data sets were divided based on location greater or less than 15 m from the active drainfield trenches. Scatter plots and R^2 values were shown and discussed in Appendix R.

Site	Location	Sample Number	Median Groundwater Specific Conductivity (µS/cm)	Median Ω.m	Mann-Whitney Comparison of BG vs. DG p-values		Mann-Whitney Comparison of DF vs. DG p-values		R^2
					µS/cm	Ω.m	µS/cm	Ω.m	
Pooled Data	BG	26	117	319	0.0565	**0.0015**	**0.0012**	0.2127	0.34
	DF	58	237	104					
	DG	69	140	116					
EC	BG	7	128	178	0.4599	0.0629	0.6876	0.1686	0.03
	DF	15	130	161					
	DG-all	22	138	79					
Res-100	BG	6	198	122	0.9746	0.2655	0.3165	0.7987	0.01
	DF	14	244	96					
	DG	19	218	93					
HS	BG	13	79	1283	0.0847	0.0678	**0.0004**	**0.0001**	0.69
	DF	29	363	81					
	DG-all	22	130	516					
HS	BG	13	79	1283	**0.0021**	**0.0003**	0.2572	0.1592	-
	DF	29	363	81					
	DG ≤ 15m	9	145	298					
HS	BG	13	79	1283	0.8375	1.0000	**0.0000**	**0.0000**	-
	DF	29	363	81					
	DG ≥ 15m	13	92	1388					
EC	BG	7	128	178	0.8622	0.0728	0.6056	**0.0490**	-
	DF	15	130	161					
	DG ≤ 15m	8	128	98					
EC	BG	7	128	178	0.3510	0.3481	0.1262	0.5557	-
	DF	15	130	161					
	DG ≥ 15m	14	139	68					

The Residential 100 (Res-100) and the education center (EC) had p-values greater than 0.05 except for one comparison completed for the education center data set (Table 5). The education center, resistivity comparison of the downgradient < 15 m data set and the drainfield data set had a p-value < 0.05 (Table 5). The sites with small OWS had median contrasts between the background and downgradient (all, ≤ 15m, and ≥ 15m) groundwater specific conductivity values < 20 µS/cm. The results and discussion for the education center, Residential 100 and Residential 200 were provided in Appendix R. The high school had the highest contrast between the background median and downgradient median groundwater specific conductivity data sets (Table 5 and Appendix R). The high school had the highest R^2 value calculated from the regression analysis between Log resistivity and groundwater specific conductivity data sets (Table 5).

High School

The high school background vs. ≤ 15 m downgradient and the drainfield vs. ≥ 15 m downgradient data set comparisons had p-values < 0.05 (Table 5). In Figure 15, the groundwater specific conductivity values decreased (plot A, Table 5) and resistivity values increased (plot B, Table 5) with increased distance from the drainfield. Additionally, nested piezometers were used to assess the vertical extent of the wastewater plume at the high school. In Figure 13, the nested piezometers 25 and 22 had groundwater specific conductivity values that increased with depth (light blue rectangles, Figure 13). The increased groundwater specific conductivity indicated wastewater influence was present at deeper depths with distance from the drainfield.

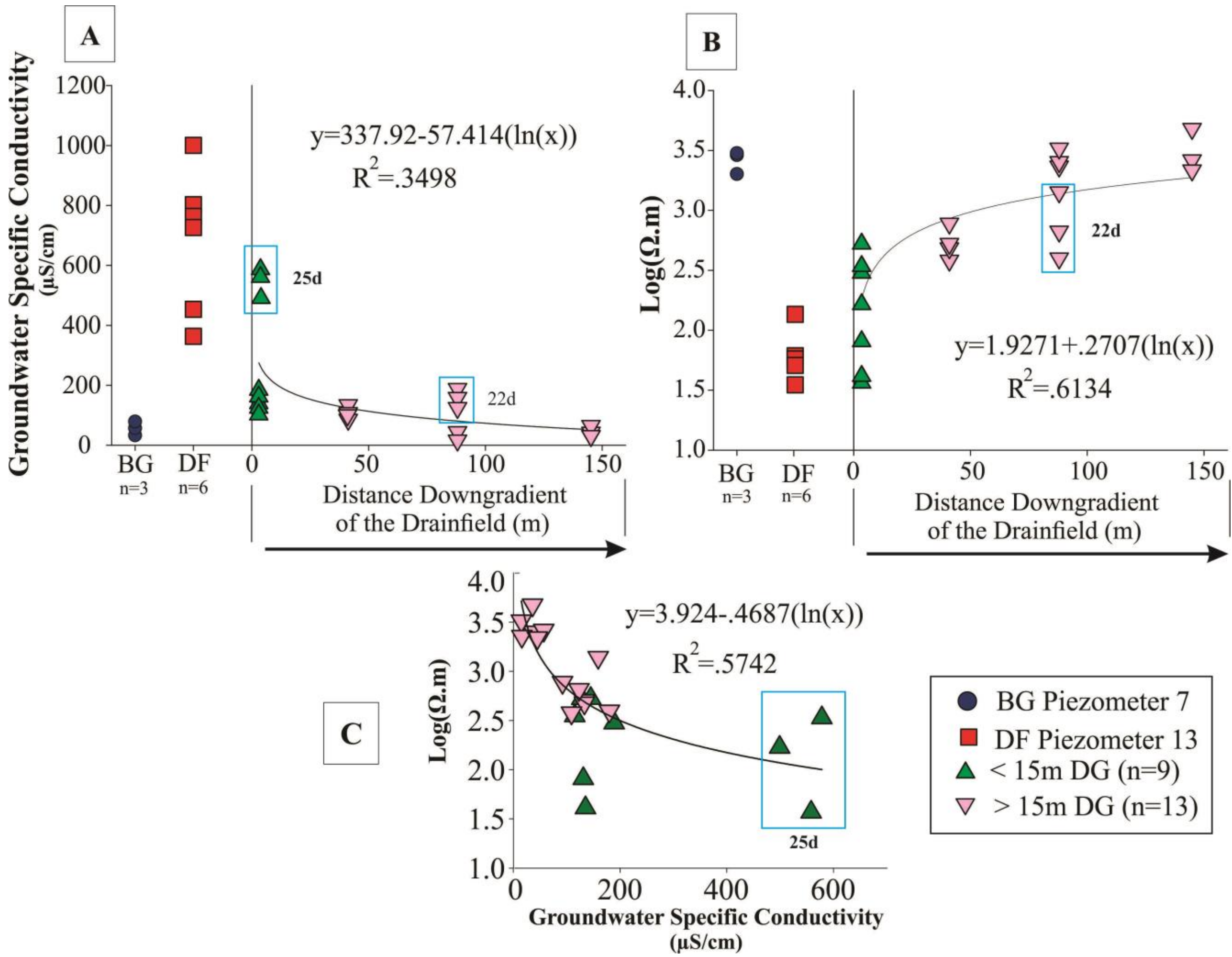

Figure 13. High school plots A, B, and C. Plot A shows groundwater specific conductivity values with distance from the drainfield (triangles) and plot B shows Log resistivity with distance from the drainfield. Both plots show reference values collected from background piezometer 7 (BG) (circles) and drainfield piezometer 13 (DF) (squares) and regression equations and R^2 values. Plot C shows the comparison of downgradient Log resistivity vs. groundwater specific conductivity values, corresponding regression equations and R^2 values. The solid blue line rectangles mark outliers.

The piezometer 25 nest was located less than 15 m from the drainfield. The piezometer 25 nest had resistivity values that ranged from 37-528 Ω.m and groundwater specific conductivity values ranged from 115-578 µS/cm (Appendix Table F2). The screened intervals for the piezometer 25 nest were 1.83-2.74 mbgs (25s), 2.73-3.64 mbgs (25m) and 3.75-4.66 mbgs (25d). The nested piezometer 25d was screened at the deepest depth of all the downgradient piezometers and had the highest downgradient groundwater specific conductivity values (499-578 µS/cm) (Figure 13, top plot). In Figure 13, the nested piezometer 25 groundwater specific conductivity values increase with increased depth. The elevated groundwater specific conductivity ($\geq$ 400 µS/cm) found at piezometer 25d was indicative of wastewater influence. Piezometer 25d also had the highest average groundwater specific conductivity (545 µS/cm; n=3) and the highest average TDN (16.61 mg/L; n=3) values and the lowest average resistivity (181 Ω.m; n=3) values of the downgradient piezometers at the high school.

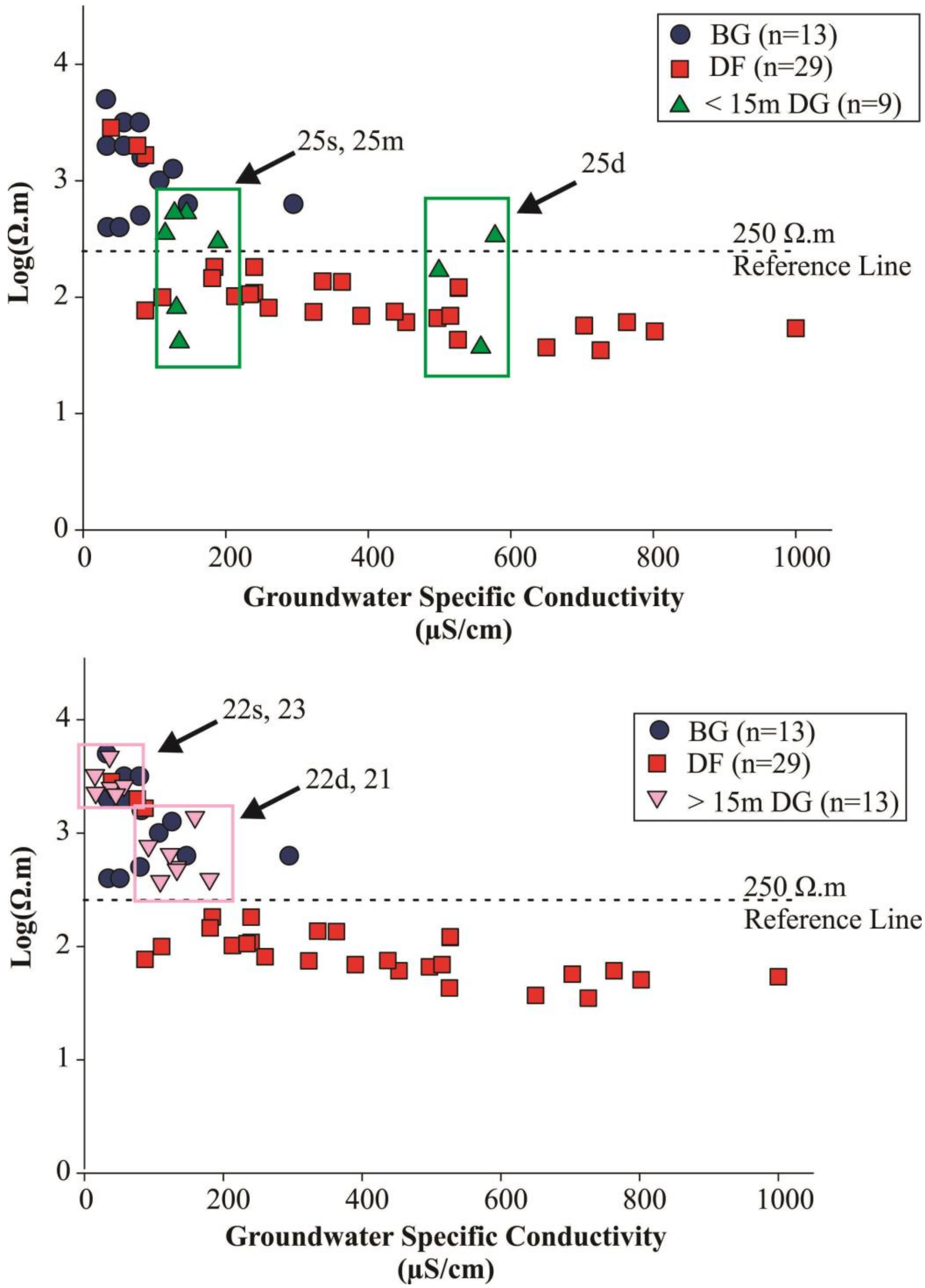

Figure 14. Two scatter plots for the high school. The plots show BG, DF, and DG values. The top plot shows Log resistivity and specific conductivity values collected from piezometers located less than 15 m DG of the high school OWS (triangles) and the bottom plot shows values collected from piezometers located greater than 15 m from the high school active OWS (upside down triangles). The colored boxes on each plot draw attention to the corresponding DG triangles. The high school BG, DF, and DG values were listed in Appendix Tables F2.

The piezometers located greater than 15 m downgradient from the drainfield had resistivity values that were > 250 Ω.m (range: 378-4718 Ω.m) and groundwater specific conductivity values < 200 µS/cm (range: 16-189 µS/cm) (Appendix Table F2). The piezometer 22 nest was located approximately 88 m downgradient of the active drainfield and consisted of piezometer 22s and 22d. Piezometer 22d was screened at 2.65-3.56 mbgs and had the second deepest screened depth interval of all the downgradient piezometers (Appendix Table F2). In Figure 14, the groundwater specific conductivity increased and resistivity decreased with depth at the nested piezometer 22. Piezometer 22d had elevated groundwater specific conductivity and lower resistivity values relative to piezometer 22s (Figure 13, and 14, bottom plot). Piezometer 22d had the highest average TDN (1.20 mg/L, n=3) of the downgradient piezometers that were located greater than 15 m from the drainfield. Overall, elevated groundwater specific conductivity values indicative of wastewater influence were collected from piezometers installed at deeper depths (25d and 22s).

Figure 15 shows the background, drainfield, and downgradient groundwater specific conductivity and resistivity values collected on 11/14/2014. In Figure 15, the downgradient resistivity values increased and the downgradient groundwater specific conductivity decreased with increased distance from the drainfield. Additionally, resistivity decreased and groundwater specific conductivity values increased with increased depth at nested piezometers 25 and 22 (Figure 15). In Appendix Figure I2 and Figure 15 areas of low resistivity < 250 Ω.m indicated wastewater influence ≥ 5 m below the screened interval of piezometers 21, 22d, and 25d.

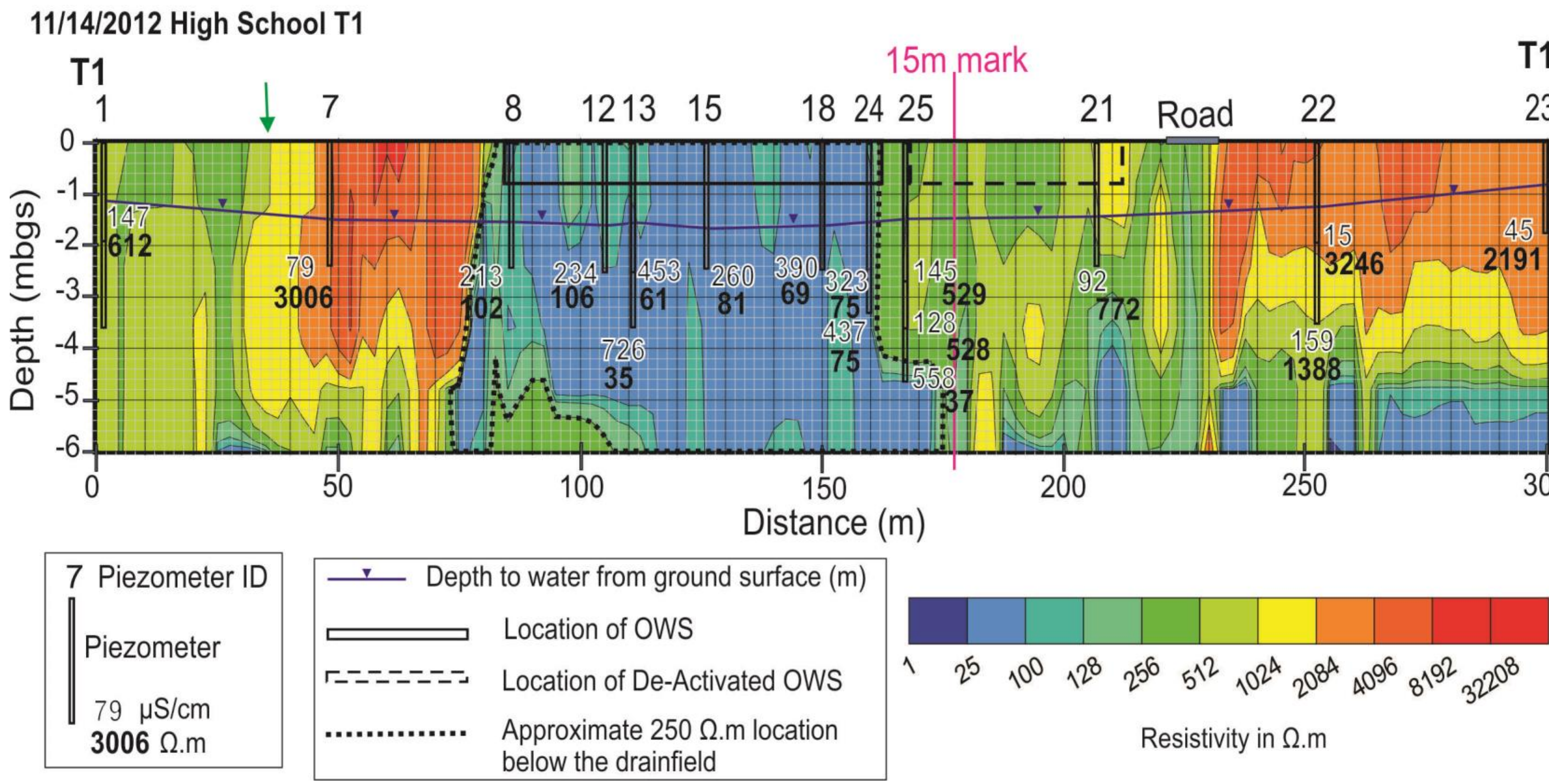

Figure 15. Resistivity T1 at the high school on 11/14/2014 (Index Map: Appendix Figure H1). Groundwater specific conductivity (µS/cm) values were listed near the bottom of or adjacent to the screened interval of a piezometer (black rectangle). On the cross-section corresponding resistivity (Ω.m) values were shown in bold black and listed below µS/cm values. The hot pink vertical line shows the 15 m marker from the active drainfield. The green arrow along the top x-axis marks the general location for a change in soil type between piezometers 1 and 7 (Appendix Table L1). Nested piezometer 25 was installed during the current study, using CCR surveys collected from Smith (2013).

The piezometer 25 groundwater specific conductivity values increased and the resistivity values decreased with increased depth (Figure 15). Piezometer 25d had the lowest resistivity (≤250 Ω.m) and the highest groundwater specific conductivity (≥200 µS/cm) value of the downgradient piezometers (Figure 15). On all survey dates the elevated groundwater specific conductivity values found at piezometer 25d indicated wastewater influence was highest at a deeper depth interval. The wastewater influences detected at piezometer 25d indicated resistivity responses were detectable downgradient of the drainfield when groundwater conductivity values were elevated approximately 200 µS/cm above background conditions.

A depth slice of a 3D survey at the high school was used in order to show a horizontal view of resistivity values at a 1.3 mbgs depth (approximate depth to water table collected from a piezometer) across drainfield and downgradient areas (Figure 16). The highest resistivity values ranged from 2084 to 32208 Ω.m (Figure 16). The elevated resistivity values were located near piezometers 8 and 9 and outside of the drainfield flow path (OSP) near piezometer 27 (Figure 16). In Figure 16, the lowest resistivity values were located within the 2 active drainfields (2 sold boxes) and ranged from 25-256 Ω.m. The resistivity values within the de-activated drainfield located downgradient of the active drainfield ranged from 256-2084 Ω.m. The resistivity values increased with increased distance downgradient of the active (Figure 16).

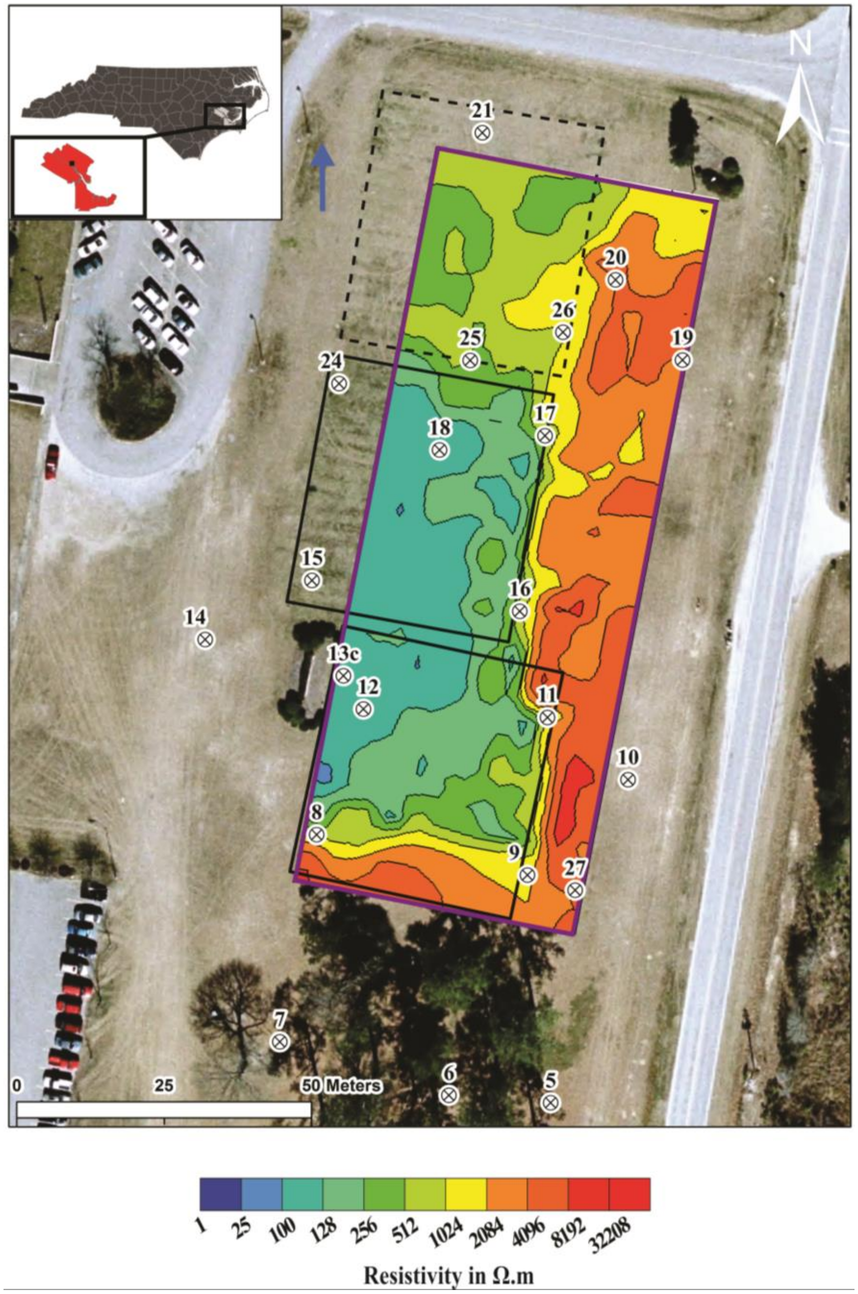

Figure 16. Aerial base map of the high school with a 3D CCR survey overlay at a depth of 1.3 m into the subsurface on 11/14/2012 (purple square). The dashed box represents a de-activated drainfield and solid line box represents the active OWS drainfield. The blue arrow represents the groundwater flow direction.

Objective 2 Summary

The high school was the only site in which the contrast between the median background and the median downgradient groundwater specific conductivity values was greater than 50 μS/cm. A decrease in groundwater specific conductivity values and an increase in resistivity values at distances greater than 15 m downgradient from the drainfield were observed at the site (Table 5). The nested piezometers 25 and 22 were used to provide estimates of the vertical extent of the wastewater plume. The elevated groundwater specific conductivity values increased and lower resistivity values indicative of wastewater influence were found at the deep nested piezometers 25d and 22d.

Objective 3: Determine if GPR can locate OWS system components across a range of drainfield sizes

GPR surveys were conducted to locate the OWS drainfield trenches and components at each site. 3D GPR surveys were conducted at the elementary school, high school, and Residential 100. GPR transects were collected at the schools, education center, and Residential 100.

During data collection, high postive (normal) polarity amplitude reflections were visible in real time on the GPR console. The locations of the reflections were marked and matched with the locations of the drainfield trenches on the OWS permit and verified with a tile drain probe. On the 2D and 3D surveys, high amplitude reflections spaced 1-2 m apart marked the locations of the drainfield trenches. The locations, approximate depth, and number of drainfield trenches were verified using OWS permits and a tile drain probe (Appendices A and B). The values were matched with the location, depth, length, and number of drainfield trenches detemined from the GPR 3D surveys and/or transects at each site (Table 6).

Table 6A and 6B show drainfield trench data collected from the OWS permit, Smith (2013) study and the current study (CR).

A. The number of active and de-activated drainfield trenches present at each site specified by the OWS permit and GPR surveys collected from Smith (2013) and the current study.

Site	**Category**	**Current Study GPR Surveys**	**OWS Permit**	**Smith (2013), GPR Surveys**
High School	Active Drainfield Trenches	32	32	32
	De-Activated Drainfield Trenches	16	16	13
Elementary School	Active Drainfield Trenches	32	32	25
	De-Activated Drainfield Trenches	-	-	-
Education Center	Active Drainfield Trenches	3	3	-
	De-Activated Drainfield Trenches	-	-	-
Residential 100	Active Drainfield Trenches	6	6	-
	De-Activated Drainfield Trenches	2	5	-

B. The length, width, thickness, and cover of the drainfield trenches at each site as listed by the OWS permit. The school cover values were determined in the field by Smith (2013) and were marked by a *. "Cover" was used as the depth to top of trench (DTOT). The depth to the bottom of the trench (DTBT) was calculated by adding the cover and thickness of each trench (Smith, 2013). The table shows the DTOT and DTBT values collcted during the current study (CR) from GPR transect and 3D surveys.

Site	OWS Permit					CR GPR survey	
	length (m)	width (m)	thickness (m)	cover (m)	DTBT (mbgs)	DTOT (mbgs)	DTBT (mbgs)
High School	38	0.6, 0.9	0.3	0.6*	0.9	0.5	0.9
Elementary School	30	0.9	0.3	0.7*	1	0.35	0.9
Residential 100	20	0.9	0.3	0.15, 0.2	0.5	0.28	0.77
Education Center	21	0.9	0.3	0.15	0.45	0.1	0.5

All of the the active drainfield trenches were identified and only 13 of the de-activated drainfield trenches were visible within the high school's drainfields due to the extent of the geophysical survey area (Figure 17). The high school's active and de-activated drainfield trenches were identified as linear red, high amplitude, normal polarity reflections in Figure 17. In Appendix Figure J1, the high amplitude reflections for each drainfield trench were visible in mapview and cross-sectional view.

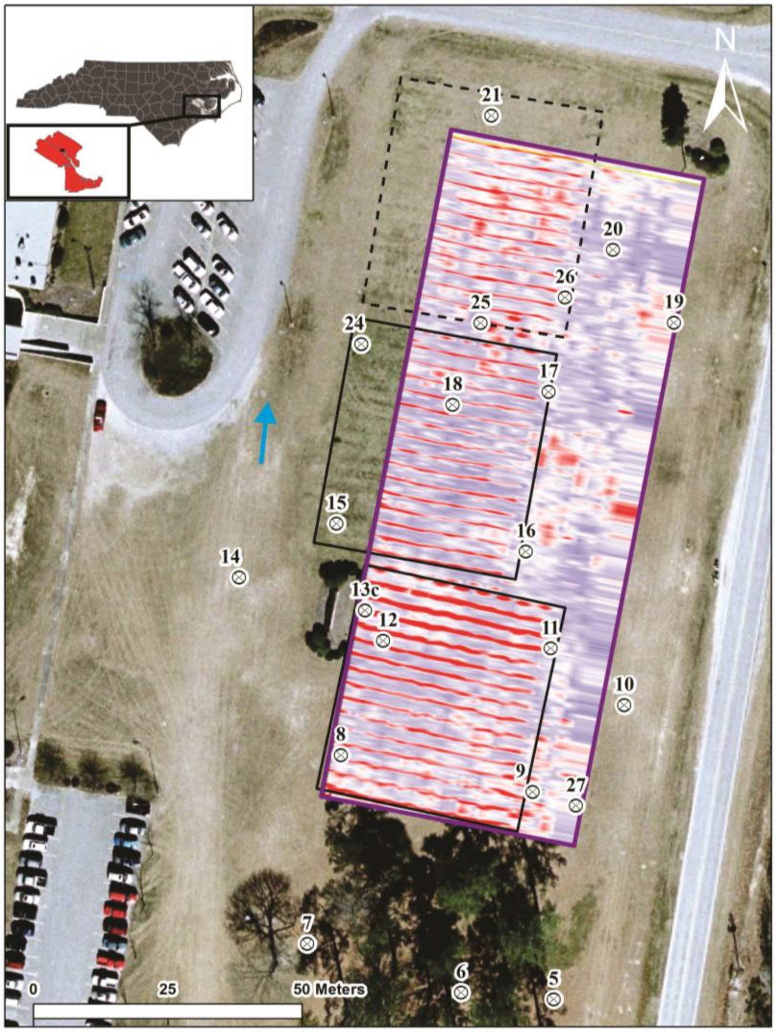

Figure 17. High school GPR 3D survey collected on 11/14/2012 at 0.62 mbgs. The locations of the geophysical survey area (solid purple box), 2 active drainfields (solid black boxes), 1 de-activated drainfield (dashed black box) and piezometers were shown. The linear red, high amplitude, and normal polarity reflections correspond to the locations of individual drainfield trenches. The areas of blue show reverse polarity reflections and areas of white show attenuation.

All 32 drainfield trenches were identified in the active drainfields, and all 16 drainfield trenches were identified in the de-activated drainfield using the GPR transects (Figure 18, Table 6A). Significant attenuation (white) was visible below the 2 active drainfields (Figure 18). High amplitude reflections within the drainfield show the locations of all the active and de-activated drainfield trenches. (Figure 18). The high school drainfield trenches were located approximately

0.5-0.9 mbgs on GPR transects and 3D surveys (Table 6B). The high school dielectric constants for the transects and surveys ranged from 17-32.

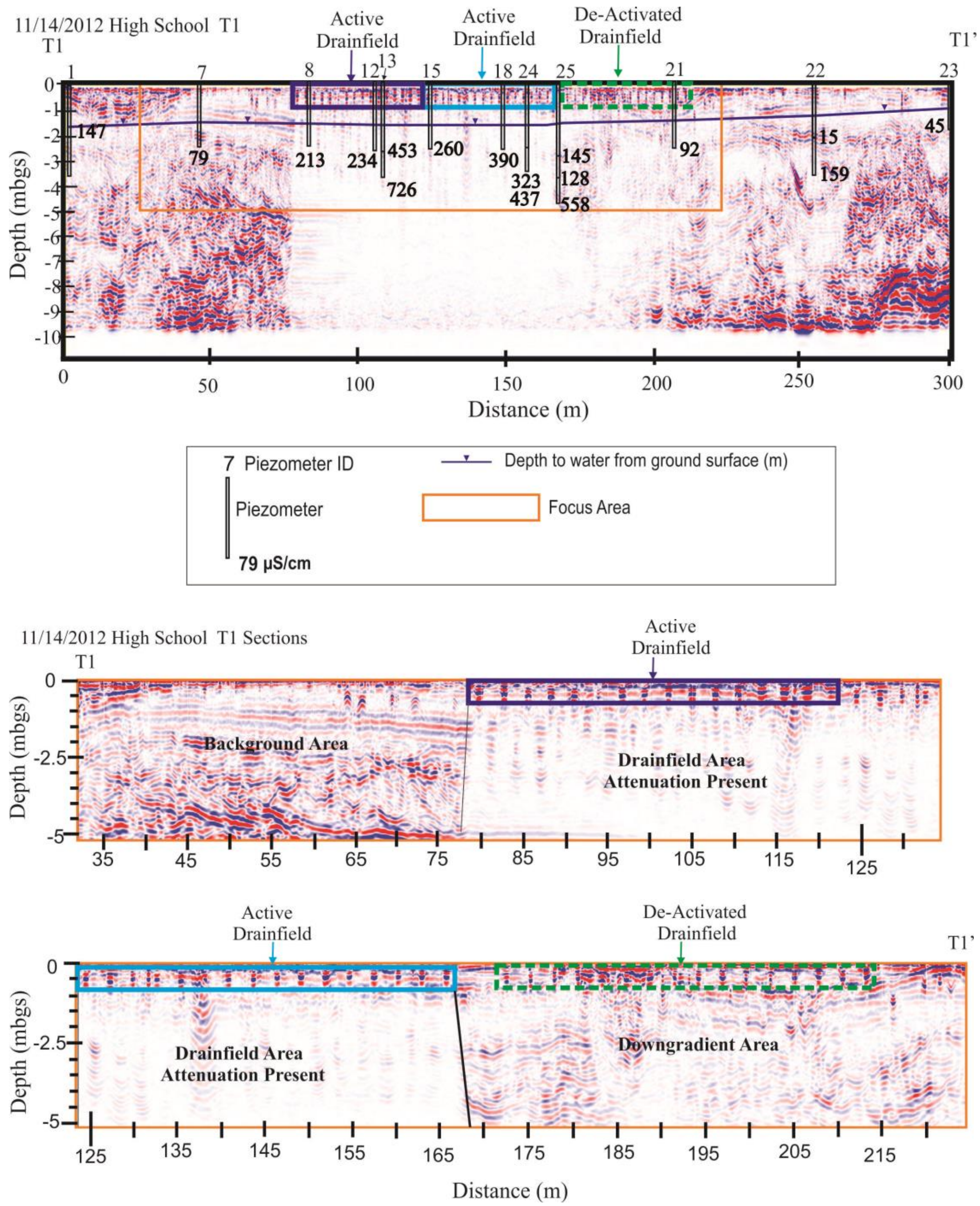

Figure 18. High school T1 collected on 11/14/2012. T1 traverses the background, drainfield, and downgradient areas at the high school (Appendix Figure H1). The locations of the 2 active drainfields (purple and light blue boxes) and the de-activated drainfield (dashed green box) were present. The focus area was expanded upon in the orange outlined boxes in order to better view the high amplitude reflections characteristic of the drainfield trenches.

Two distribution boxes and 26 of the 32 drainfield trenches were identified on the GPR 3D surveys conducted at the elemetnary school (Figure 19). The missed drainlines were a result of the extent of the survey area being slightly smaller than the drainfield due to obstructions at the site.

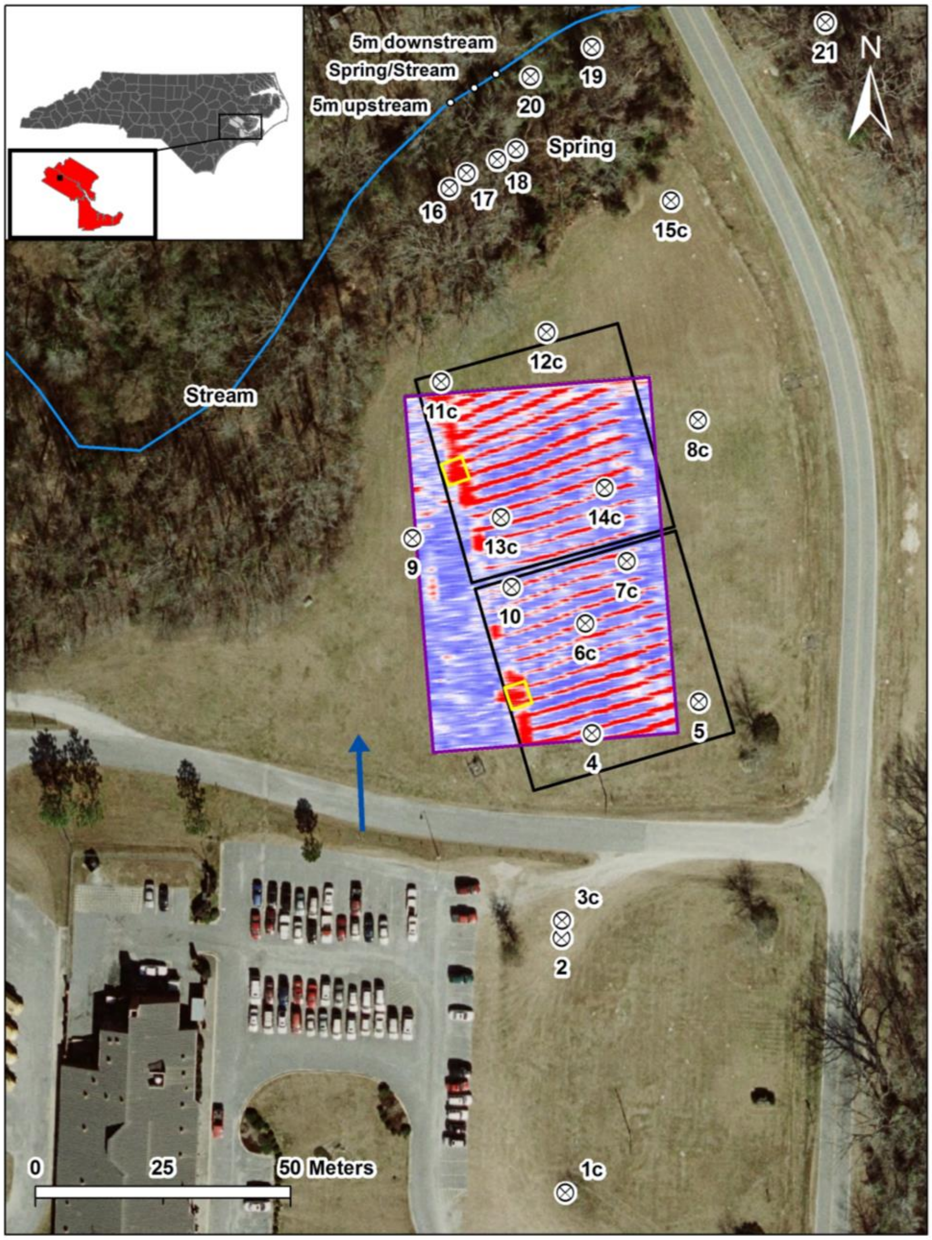

Figure 19. Elementary school GPR 3D survey collected on 3/25/2013 at 0.65 mbgs depth. The locations of the geophysical survey area (solid purple box), 2 active drainfields (solid black box), and piezometers were included in the figure. The red lines represent high amplitude, normal polarity reflections. The blue represents reversed polarity reflections and white represents attenuation. The yellow boxes show the locations of both OWS distribution boxes that were characterized by high amplitude reflections (red).

The elementary school drainfield trenches were located approximately 0.35-0.9 mbgs on the GPR transect and 3D surveys (Table 6B). The elementary school dielectric constants collected from GPR surveys and transects ranged from 16-28. Additional transects collected on 11/19/12 and 9/10/12 that traverse the background and drainfield areas at the elementary school may be found in Appendix Figure J2. All 32 elementary school drainfield trenches were identified in Figure 20 (Table 6A).

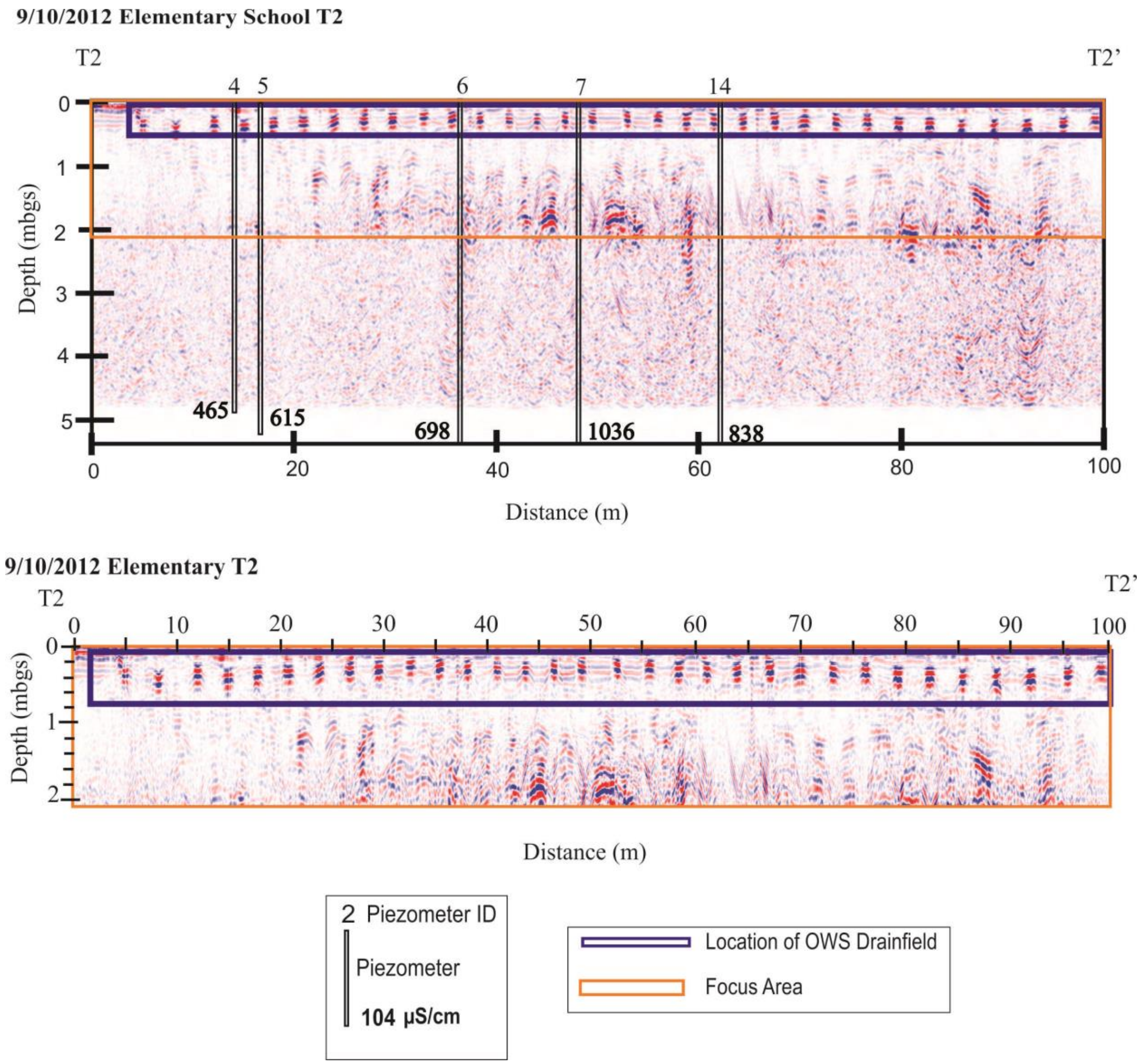

Figure 20. Elementary school, transect 2 collected on 9/10/2012 (Appendix Figure H2). The transect traverses the drainfield and shows 32 high amplitude reflections within the drainfield area (purple box).

Six Residential 100 active drainfield trenches and 1 de-activated drainfield trench were identified using GPR 3D and transect views (Figure 21 and Table 6A). A french drain, installed in 2004, was identified and located approximately 3 m upgradient of the active drainfield and 7.6 m downgradient from the de-activated drainfield trench identified on the GPR 3D survey (Figure

21). The 3D survey grid area was limited based on the location of obstructions. Additionally, a fenced-in playground attatched to the house prevented the extension of the survey area into the de-activated drainfield area (Figure 21).

Figure 21. Residential 100 GPR 3D survey collected on 7/16/12 at a depth of 0.3 mbgs (outlined in purple). The locations of the active drainfield (solid black box), de-activated drainfield (dashed black line) and the french drain (FD) given on the OWS permit matched with the GPR high amplitude normal polarity reflection locations. Additonally, reverse polarity reflections (blue) not shown on the permit were identified on the GPR survey and were marked by arrows and labeled RP.

The Residential 100 drainfield trenches were located approximitly 0.28-0.77 mgbs on the GPR transect and 3D surveys (Table 6B). The Residential 100 dielectric constants ranged from 10-25. To obtain a cross-sectional view of the drainfields, Transect 4 was collected at

Residential 100 on 9/17/2012 (Figure 22). All the active drainfield trenches were identified at a deeper depth relative to the high amplitude reflections associated with de-activated drainfield trenches (≤ .5 mbgs) (Figure 22, dashed box vs. solid box).

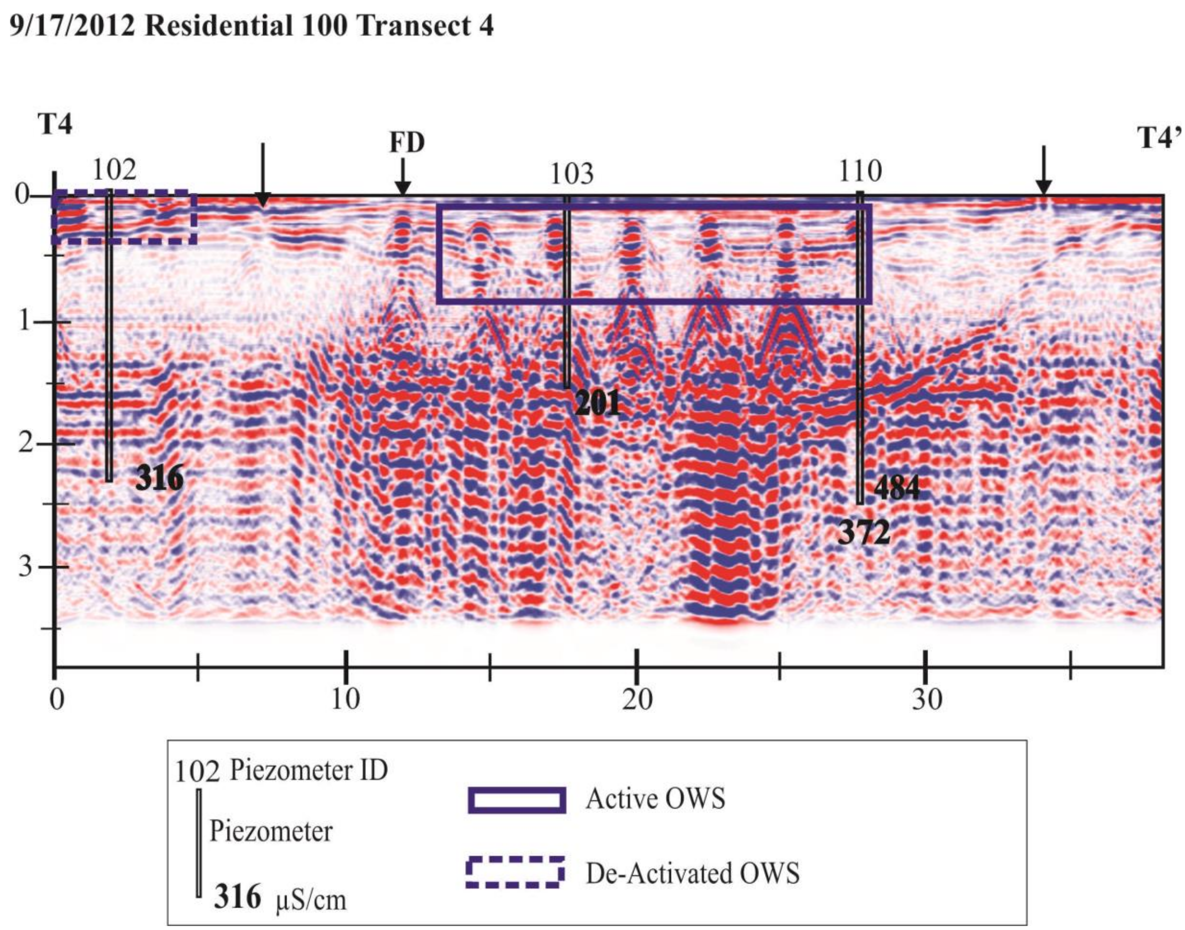

Figure 22. Residential 100, transect 4 collected on 9/17/2012. Transesct 4 was conducted with the antenna oriented perpendicular to the orientation of the drainfield trenches and traversed the drainfield area (Appendix Figure H4). The figure shows 2 high amplitude reflections representative of the de-activated drainfield trenches (dashed box) and 6 high amplitude reflections representative of the active drainfield trenches (solid black box).

The education center was a smaller scale site with only 3 drainfield trenches. Due to landscaping features a 3D survey could not be completed but the location of the pipes was verified in the field using the education center OWS permit and the GPR transects. A tile drain probe was not successfully used at the site due to the presence of polystrene chips used instead of gravel fill when the education center trenches were installed.

The education center's 3 drainfield trenches were identified on Transect 1 and 2 (Figure 23). Both transects were conducted with the GPR antenna perpendicular to the drainfield trench orientation (Appendix H). The ATFS drainfield trenches ranged from approximately 0.1-0.5 mbgs on GPR Transect 1 and 2 (Table 6B). The education center dielectric constants collected from the transect surveys ranged from 10-23.

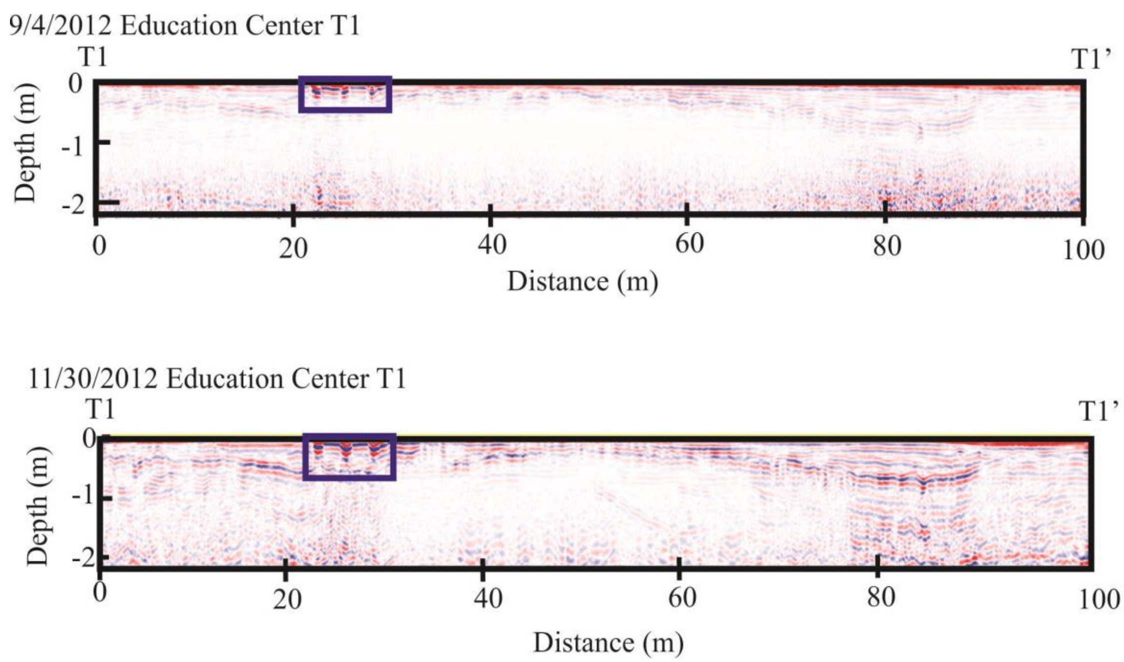

Figure 23. T1 collected at the education center. The high amplitude reflections located within the active drainfield box mark the location of the 3 drainfield trenches. The education center transect locations were shown in Appendix Figure H3.

The GPR transects and surveys were used to locate the drainfield trenches and estimate the location of the trenches below the ground surface (Table 6). All drainfield trenches were located using the GPR surveys and transects (Table 6).

Discussion

Discussion: Objective 1: Determine if CCR surveys could detect resistivity responses to increases in groundwater specific conductivity associated with wastewater inputs to drainfields across a range of systems

CCR surveys were successfully used to identify areas of low resistivity (< 250 Ω.m) within the drainfield at the sites with large OWS. The areas within the drainfield indicative of wastewater influence were characterized by resistivity values < 250 Ω.m and groundwater specific conductivity values > 200 µS/cm. The wastewater influence within the drainfield was successfully identified when the contrasts between the median background and drainfield groundwater specific conductivity values were > 280 µS/cm.

Previous researchers have used geophysical techniques to identify and characterize low resistivity wastewater or leachate plumes in the subsurface. Frohlich et al. (1994) determined that resistivity values ≤ 230 Ω.m were indicative of a landfill leachate plume in well-sorted sands and glacial sediments, near Provincetown, Cape Cod, Massachusetts. Research by Amidu and Olayinka (2006) used geophysical surveys to locate wastewater sourced from a septic tank at the Ibadan University, located in Ibadan, southwestern Nigeria (Table 1). Resistivity values were collected nearby the septic tank in conjunction with specific conductivity values collected from soil samples (Amidu and Olayinka, 2006). The site subsurface was characterized by sandy to silty, clay media with some gravel, and the study was conducted during the dry season when the water table was ≥10 mbgs (Amidu and Olayinka, 2006). Amidu and Olayinka (2006) found the majority of resistivity values collected within close proximity to the septic tank were generally characterized by resistivity values ≤ 200 Ω.m. Amidu and Olayinka (2006) and Frohlich et al. (1994) used traditional resistivity approaches in which galvanic electrodes were inserted into the ground. Fewer studies have used CCR.

Research by Roy et al. (2009) successfully used CCR surveys to detect wastewater-affected groundwater with distance from the drainfield in British Columbia, Canada. Researchers determined that CCR surveys were a non-invasive, relatively fast method to locate low resistivity areas influenced by wastewater in a higher resistivity glacial till subsurface (Roy et al. 2009). Roy et al. (2009) recommended incorporating water quality data collection and analysis with geophysical survey collection in order to ground truth the resistivity values collected from the surveys. In coastal North Carolina, Smith (2013) successfully utilized CCR in conjunction with water quality data analysis to locate wastewater plumes below the active OWS drainfield at 2 schools.

Smith (2013) evaluated possible controls on the resistivity values collected from CCR surveys conducted across background and drainfield areas at both schools. The controls evaluated included: groundwater specific conductivity, porosity, water level, and hydraulic conductivity (Smith, 2013 and Loke, 2000). Of the 4 controls Smith (2013) found an inverse relationship between Log resistivity and groundwater specific conductivity ($R^2 > 0.5$) at the 2 schools. Smith (2013) also found significantly different data sets sourced from background and drainfield locations for resistivity and groundwater specific conductivity ($p < 0.05$). The current study and Smith (2013) results for groundwater specific conductivity and resistivity comparisons were listed in Appendix K.

Researchers in Smith (2013) and the current found that wastewater influence within the drainfield was characterized by CCR survey resistivity values < 250 Ω.m and groundwater specific conductivity values > 200 µS/cm at the 2 schools. The Smith (2013) and current study resistivity values indicative of wastewater influence below the drainfield (< 250 Ω.m) were similar to the resistivity values characteristic of wastewater influence collected by Amidu and Olayinka, (2006) (< 200 Ω.m) and Frohlich et al. 1994 (< 230 Ω.m).

In the current study and Smith (2013) the elementary school had a weaker resistivity response to changes in groundwater specific conductivity relative to the high school (Appendix Table K2). Smith (2013) attributed the elementary school's weaker resistivity response to the site's deep water table (Appendix V). In both studies, the high school had a shallower water table closer to the surface and the elementary school water table was located at deeper depths (Appendices E and V). Smith (2013) determined that the sensitivity of resistivity responses to changes in groundwater specific conductivity tended to decrease with increased water table depth (Appendix V). Additionally, Humphrey et al. (2014) found that there was a significant difference between the 2 elementary school drainfields' depth to water table (approximately 1.65 m difference). The significant differences in the depth to water table within the elementary school's 2 drainfields may have further contributed to decreased resistivity sensitivity to changes in groundwater specific conductivity.

Research by Humphrey et al. (2014) assessed the spatial distribution of fecal indicator bacteria (FIB) at the high school and elementary school. The study utilized FIB as an indicator for the presence of a biomat within the drainfield. The development of the biomat within the drainfield can reduce the infiltration rates and provide additional treatment to wastewater inputs especially at sites with sandy soils similar to the schools. Research by Humphrey et al. 2014 found that the high school LPP system had a more uniform distribution of FIB in groundwater beneath the drainfield in comparison to the elementary school. The uniform wastewater dispersal may have reduced the development of a biomat within the drainfield or allowed a more even development of a biomat within the drainfield at the high school relative to the elementary school (Humphrey et al. 2014). The presence of an uneven biomat at the elementary school could reduce infiltration rates and disrupt uniform wastewater dispersal in areas where the biomat was less developed within the drainfield (Humphrey et al. 2014 and Beal et al. 2006).

Subsequently, Humphrey et al. (2014) found that the groundwater specific conductivity was more evenly distributed at the high school due to the LPP system in comparison to the elementary school. The uniform wastewater dispersal may have allowed for a more sensitive resistivity response to changes in groundwater specific conductivity at the high school relative to the elementary school. Researchers found significant differences in groundwater specific conductivity between the elementary school's 2 drainfields (Humphrey et al. 2014). The elementary school drainfield had a 206 µS/cm difference in average groundwater specific conductivity (Humphrey et al. 2014). In the current study, resistivity responses may not have been sensitive enough to precisely detect the differences in groundwater specific conductivity between the 2 elementary school drainfields. The weaker resistivity response may be due to the differences in groundwater specific conductivity between the 2 drainfields.

Aside from the elementary school and high school, the current study incorporated additional sites with small OWS. Research by Humphrey et al. (2010) and O'Driscoll et al. (2014) successfully utilized CCR surveys to locate low resistivity, OWS wastewater plumes at 2 residential sites in Beaufort County, North Carolina. The 2 residential sites were characterized by high resistivity, sandy soils and had small OWS with maximum design flows of 1600 L/day. On the CCR survey dates there was a significant groundwater specific conductivity contrast between the background and drainfield locations > 300 µS/cm (Humphrey et al. 2010). In the current study the sites with small OWS and maximum design flows <1600 L/day had contrasts between background and drainfield median groundwater specific conductivity values that were less than <50 µS/cm. The contrasts in groundwater specific conductivity were not great enough to successfully use CCR surveys to identify wastewater inputs on survey dates at the sites with small OWS. Ultimately, in order to detect the areas influenced by wastewater inputs using CCR surveys a sufficiently high conductivity contrast between background conductivity and drainfield conductivity was necessary (Urish, 1983). The current study sites with small OWS site specific characteristics that may have contributed to the decreased variability in groundwater specific conductivity and the consequential weak CCR resistivity responses were discussed below.

The relatively low drainfield groundwater specific conductivity values may have been diluted due to the shallow water table at Residential 100 where the average water table on survey dates was 0.5 mbgs (n=20). Iverson (2013) assessed TDN values at Residential 100 and found that dilution could have been a significant factor influencing TDN value reductions from the tank to the drainfield piezometers. Iverson (2013) reported that the average water table on sampling dates was 0.89 mbgs (n=69) at Residential 100. In the current study, low wastewater inputs and dilution due to the shallow water table at Residential 100 may have resulted in the low contrast between background and drainfield groundwater specific conductivity values.

The Residential 100 resistivity values were also relatively low across background and drainfield piezometers and had low median contrasts. Research by Iverson (2013) and Humphrey et al. (2013) noted a relatively high clay concentration present in the soils at Residential 100 compared to the schools. The current study estimated that Residential 100 had the lowest estimated hydraulic conductivity range (0.12 to 1.21 m/day) and lowest specific yield range (8.4-25.8) (Appendix Table L1 and L2). Clay was characterized by low resistivity, 7-100 Ω.m, a specific yield of 8, and specific retention of 48 and a total porosity of 50% (Samouëlian et al. 2005 and Heath, 1983). Comparatively, sand has a high resistivity (700-10,000 Ω.m) and generally would be characterized by a low specific retention (3) and high specific yield (22) with a porosity of 25% (Samouëlian et al. 2005 and Heath, 1983). The presence of highly conductive soils, such as silt or clay, may have reduced the resistivity sensitivity to the wastewater inputs below the Residential 100 drainfield. The presence of low resistivity subsurface media such as clay or silt and a shallow water table (average 0.5 mbgs; n=20) within the background and drainfield areas may have masked the expected low resistivity wastewater inputs within the drainfield.

Residential 100 had the highest median groundwater specific conductivity collected from the background area (Table 4). The elevated groundwater specific conductivity values may have been influenced by OWS inputs from residential systems located upgradient of the Residential 100 OWS. The upgradient residential OWS were located approximately 114 – 120 m from the Residential 100 OWS. The residential OWS located adjacent to Residential 100 were offset by approximately 15-33 m. The influence from nearby OWS wastewater inputs may have contributed to low contrasts between median background and drainfield values at Residential 100.

The education center had a small OWS with a maximum design flow less than 1600 L/day. CCR surveys and water quality data were collected within a month of the system installation. The system usage was estimated to have been sporadic based on the education center calendar page, which showed only 1-2 weekend events scheduled a month (ATFS, (2014)). The OWS wastewater inputs were expected low, and the contrast between background and drainfield median groundwater specific conductivity values was 2 µS/cm. The education center was characterized by a deeper water table present at the education center, similar to the elementary school water table. The increased depth to water table may have reduced resistivity sensitivity to the corresponding groundwater specific conductivity values.

Research by Urish (1983) established that a significant difference between the native media (low conductivity background media) and the target media (high conductivity wastewater plume) conductivity would be required to adequately locate a wastewater plume below the drainfield using CCR. Collectively in the current study and Smith (2013) sites in which contrasts between median background (native media) and drainfield (target media) groundwater specific conductivity values were greater than 280 µS/cm had resistivity responses below the drainfield < 250 Ω.m indicative of wastewater influence. The groundwater specific conductivity values >200 µS/cm and corresponding low resistivity values < 250 Ω.m indicative wastewater influence were found beneath the drainfield at the sites with large OWS and maximum design flows > 11,340 L/day. The sites with small OWS and maximum design flows < 1,600 L/day had low contrasts between background and drainfield median groundwater specific conductivity (<50 µS/cm). The contrasts between background and drainfield groundwater specific conductivity were not significant enough to result in a significantly low resistivity response beneath the drainfield characteristic of wastewater influence.

Discussion: Objective 2: An assessment and comparison of resistivity and groundwater specific conductivity between background, drainfield, and downgradient areas at the high school.

The high school resistivity values increased with increased distance from the drainfield and groundwater specific conductivity values decreased with increased distance from the drainfield (Figure 13). In addition, groundwater specific conductivity increased and resistivity decreased with increased depth at the high school (Figure 13 and Appendix Figure I2).

Research has shown that the area influenced by wastewater inputs below the OWS drainfield was characterized by elevated specific conductivity and decreased resistivity values (Smith, 2013 and Amidu and Olayinka 2006). Smith (2013) established that the high school study area consisted of predominantly sandy, unconsolidated, siliciclastic sediments across background and drainfield locations. The current study background median resistivity values were > 800 Ω.m. The elevated resistivity values were characteristic of sandy unconsolidated sediments. Loke (2004) estimated the resistivity for gravel and sandy unconsolidated sediment ranged from 750-10,000 Ω.m (Loke, 2004). In Smith (2013) and the current study, the high school drainfield resistivity values indicative of OWS wastewater influence were characteristically < 250 Ω.m below the drainfield. The potentially large contrasts in resistivity between the native sediment and areas influenced by wastewater inputs indicated that resistivity values may be used to detect wastewater influence downgradient from the drainfield. Smith (2013) recommended assessing resistivity responses to groundwater specific conductivity values with distance downgradient of the OWS drainfield.

Previous research has had success identifying the plume with distance from the drainfield, especially in areas where wastewater inputs were significant and the native subsurface media was characterized by the high resistivity sediments. Roy et al. (2009) used a CCR OhmMapper to locate the wastewater plume downgradient of the OWS drainfield in glacial till and boulder media. The water table was approximately 0.5 mbgs and the depth to bedrock was greater than 5m (Roy et al. 2009). The expected wastewater inputs were 12,000 L/day (Roy et al. 2009). The resistivity range for glacial sediments was 75-10,000 Ω.m and approximately 750-10,000 Ω.m for unconsolidated sand and gravel (Samouëlian et al. 2005 and Loke, 2004). The background area was characterized by bulk EC values less than 300 μS/cm (Roy et al.

2009). The wastewater plume was characterized by bulk EC > 450 µS/cm. (Roy et al. 2009). Roy et al. (2009) successfully utilized CCR to locate a low resistivity plume in high resistivity subsurface sediments downgradient of the drainfield. Groundwater quality samples were not collected from installed piezometers or wells but surface water samples were collected to correlate with the EC values collected from CCR surveys. Roy et al. (2009) did not assess possible changes in resistivity relative to specific conductivity or resistivity sensitivity to changes in specific conductivity with increased distance from the drainfield.

Amidu and Olayinka (2006) used geophysical surveys to map wastewater sourced from a septic tank at the Ibadan University, located in Ibadan, southwestern Nigeria (Table 1). Amidu and Olayinka (2006) found the majority of resistivity values collected within close proximity to the septic tank were generally characterized by resistivity values ≤200 Ω.m. The resistivity values collected from areas further away from the septic tank were characterized by resistivity values ≥200 Ω.m values (Amidu and Olayinka, 2006). These results were similar to the current study results in which the high school resistivity values collected approximately 9 m from the drainfield ranged from 37-529 Ω.m and the resistivity values collected from piezometers > 15 m downgradient of the drainfield ranged from 378-4,718 Ω.m (Figure 13, 15 and 16). The results from both studies showed an overall increase in resistivity values with increased distance from the wastewater dispersal source. The university resistivity values were greater than 200 Ω.m at distances greater than 10 m from the tank (transect 7) and the resistivity values were greater than 300 Ω.m at distances greater than 20 m from the tank (transects 8 and 9) (Amidu and Olayinka, 2006). Similarly, in the current study, piezometers located greater than 15 m from the drainfield had resistivity values > 300 Ω.m, and a piezometer located 145 m from the drainfield had resistivity values > 2,000 Ω.m. Low resistivity values <250 Ω.m indicative of wastewater influence at depths ≥ 4 mbgs downgradient of the drainfield were identified at the high school.

Researchers found that at the high school resistivity values increased and groundwater specific conductivity values decreased with increased distance from the wastewater source (Figure 13). Researchers also successfully used CCR at the high school to locate a low resistivity wastewater plume (< 250 Ω.m) approximately 9 m downgradient of the drainfield at a depth ≥ 4 mbgs.

CCR Survey Limitations

In the current study, the resistivity resolution and investigation depth were two limiting factors that influenced the resistivity values selected at the piezometer screened interval. CCR survey resistivity resolution can be reduced with increased penetration depth (Loke, 2004). Research by Smith (2013) found that the schools' resistivity resolution decreased at depths greater than 6 mbgs and the skin depth was exceeded at depth > 8 mbgs (Appendix S). The CCR survey investigation depth and resistivity resolution can also be reduced in highly conductive regions (Geometrics, 2001). The elevated conductivity can contribute to signal loss (attenuation) by impairing the current flow through the subsurface (Geometrics, 2001 and Loke, 2000). The apparent resistivity values collected in the field were converted to actual resistivity estimates using the RES2DIN V software. The software program divides the subsurface into a number of rectangular blocks and uses a least-squares inversion scheme to determine the appropriate resistivity value for each block (Loke, 2004). Sharp contrasts in actual resistivity values or resistivity anomalies present may have altered the measured resistivity value output by the program. In addition, CCR survey areas can be limited by obstructions including fences, trees, signs, and particularly nearby electric lines or electric dog fences.

Discussion: Objective 3: Application of GPR to locate OWS components at the elementary school, high school, education center, and Residential 100

The current study utilized the same GPR data collection method as Smith (2013) to locate OWS components. On GPR surveys, Smith (2013) successfully located all of the active drainfield trenches and 13 of the 16 de-activated drainfield trenches at the high school and 25 of the 32 active drainfield trenches at the education center (Table 6A). The drainfield trenches were identified on the GPR surveys as high amplitude normal polarity reflections. The locations of the reflections corresponded with the locations of the OWS drainfield trenches given on OWS permits and the locations determined in the field using a tile drain probe. Smith (2013) found that GPR surveys conducted with lower frequency antennas (200 MHz) perpendicular to OWS drainfield trench orientation could be successfully used to locate OWS drainfield trenches in moderately saturated sandy sediments in which the water table was below the drainfield at 2 schools in coastal, North Carolina.

In order to build on research by Smith (2013) the 3D survey areas at the schools were expanded and additional transects were collected at the sites to attempt to identify all drainfield trenches. At the schools all of the active and inactive drainfield trenches were successfully identified within the transect view (Figures 18 and 20). At the elementary school the 2 distribution boxes were identified in map view (Figures 19). Unfortunately, even after the 3D survey area was expanded not all drainfield trenches were identified in map view at the schools. Expanding the study area further was prohibited at both sites due to the locations of obstacles including trees, wooded areas, signs, and light poles. Using the 3D map view only 13 of the 16 inactive drainfield pipes were identified at the high school and 26 of the active drainfield pipes were identified at the elementary school (Figures 17 and 19; Table 6; Appendix Figure H1 and

H2). Table 6 shows the number of drainfield trenches identified on the GPR surveys at each site during the current study and in Smith (2013).

Smith (2013) reported that high amplitude reflections identified as drainfield trenches on GPR surveys were located approximately 1 mbgs at the schools and the approximate depth to the top of the drainfield trenches, measured in the field, was 0.6 mbgs at high school and 0.7 mbgs at education center. Smith (2013) found that the two depths to the top of the trench, calculated in the field, were within 0.4 m of the approximate 1 mbgs at which the drainfield trench was identified by high amplitude reflections on the GPR surveys (Smith, 2013). The current research, as mentioned above maintained the same GPR data collection process in the field as Smith (2013), but altered the data processing methodology. The current study incorporated the "Structure Identification" process that removes the delay and additional horizontal background noise. The delay removal was set to the antenna frequency and factory standards. The addition of the "Structure Identification" step and removal of the position delay step used in the Smith (2013) methodology was the only difference between the current study and Smith (2013) GPR data processing procedure. The "Structure Identification" step was used to provide a clearer view of the drainfield trenches. The approximate depth of the drainfield trenches at the high school ranged from 0.5-0.9 mbgs. The high school drainfield trenches were most evident at 0.62 mbgs (n=3). The drainfield trenches at the education center ranged from 0.35-0.9 mbgs, and the drainfield trenches were most evident at 0.65 mbgs (n=3). In the current study, the estimated depths to the bottom of the trenches (DTBT), determined using GPR transects, were similar to the DTBT values calculated using Smith (2013) cover (mbgs) values, estimated using a tile drain probe, and OWS permit information (Table 6B). Cover refers to the sediment placed over the drainfield trench and was often composed of sand or local soils. In the current study, the depths to the top of trenches (DTOT) collected from the GPR surveys and the DTOT values collected using a tile drain probe in Smith (2013) varied at the high school by 0.1 m and at elementary school by about 0.35 m. For both sites the water levels on all survey dates were below the drainfield trenches. The values collected during the current study were within close proximity to the values collected at the schools during Smith (2013). The application of the "Structure Identification" step was helpful in generating a closer depth to top of the trench for the school's trenches.

GPR was also utilized at 2 small scale sites: education center and Residential 100. There were 3 active drainfield trenches at the education center and 6 active drainfield trenches at Residential 100. During OWS installation, the drainfield trenches at the education center were installed with polystrene chip fill unlike the schools and Residential 100 that used gravel fill. The polystrene chips present a problem when attemtping to locate the trench using a tile drain probe, since it was hard to detect when the probe intersects or comes into contact with the chips. Generally, when gravel fill was used a characteristic crunch sound was emitted when the probe intersects gravel; this does not occur where the chips were used as trench fill. Due to this problem the GPR was used to locate the drainfield trenches and significantly reduced time spent locating trenches with the probe.

The education center OWS was installed during February 2012. All 3 drainfield trenches were identified on all survey dates using GPR transects. The high amplitude, positive polarity reflections representative of the drainfield trenches were shown in Figure 23 on dates 9/4/2012 and 11/30/2012 on transect 1. The approximate depth to the top and bottom of the education center trenches, collected from GPR transect 1 and 2, were approximately 0.1-0.5 mbgs, which matched closely with the depth to the top and to the bottom of the trench calculated from the

OWS permit: 0.15 (DTOT) -0.45 (DTBT) mbgs (Table 6B). The average groundwater levels on all survey dates for the drainfield piezometers were below the trench mbgs depth.

When conducting GPR surveys the investigation depth and resolution of the data can be reduced by a shallow water table, high clay content, and in areas where the electrical resistivity of the subsurface was low (Olhoeft,1986 and Baker 2007). The relatively higher clay concentration and shallow water table at Residential 100 provided an opportunity to utilize the GPR to locate OWS components in a different environment compared to the education center, the elementary school, and the high school. Research by Roy et al. (2009) successfully used GPR to locate a septic field in a glacial till subsurface environment with a shallow water table (approximately 0.5 m).

Iverson (2013) found that at Residential 100 the vertical separation was less than 0.1 mbgs. The vertical separation distance was the distance between the bottom of the trench and water level (Figure 1). In the current study the average water level collected from drainfield piezometers on survey dates was 0.3 mbgs (n=14) and based on the OWS permit the activated drainfield trenches were installed with a depth to top of trench equal to 0.15 mbgs and a depth to bottom of trench equal to 0.5 mbgs. On all survey dates the drainfield pipes were believed to be filled or partially filled and GPR surveys were conducted with the antenna oriented perpendicular to the orientation of the drainfield trenches. Allred (2013) used GPR to locate plastic agricultural drainage pipes at a depth interval of 0.46 m to 0.76 mbgs in clay-loam soils under saturated and unsaturated conditions using a 250 MHz antenna. The results of the study indicated that antenna orientation perpendicular to the drainage trenches provided the strongest reflections under moderately dry soil conditions with empty air-filled pipes (Allred, 2013). The antenna orientation parallel to the drainage trenches provided the strongest reflections under saturated conditions with water-filled or partially water-filled pipes (Allred, 2013). In the current study, the orientation of the antenna perpendicular to the pipes under saturated conditions was selected due to the location obstacles and in order to incorporate all the active drainfield trenches in the survey. At the Residential 100 all 6 of the active drainfield trenches were successfully identified on the GPR 3D and transect surveys. The depth to the top and bottom of the trench on the surveys ranged from approximately 0.28 (DTOT) -0.77 (DTBT) mgbs (Table 6). On the OWS permit the depth to the top and bottom of the active drainfield trenches ranged from 0.15-0.5 mbgs. The trench depth to top and bottom values using the GPR surveys compared to the permit values varied by approximately 0.13 m at the top of the trench and 0.27 m variance at the bottom of the trench.

On the Residential 100 GPR surveys, additional structures were identified including two inactive drainfield trenches and a French drain (Figure 21, 22, and Appendix Figure J3). The de-activated drainfield trenches and French drain were characterized by high amplitude reflections. The de-activated trenches were located at shallower depths (mbgs) relative to the active drainfield trenches (mbgs). Two reversed polarity reflections were also located on the GPR surveys that were not marked on the OWS permit (Figure 21, 22, and Appendix Figure B4 and J3). To identify the two reverse polarity reflections, excavation at the locations of the reflections shown on the GPR would need to be completed, but permission to do so was not granted at Residential 100.

During the current study active and de-activated drainfield trenches were identified as high amplitude reflections on combined 3D surveys and transect views (Table 6A). Overall, the locations of the drainfield trench depth to top and depth to bottom varied by approximately 0.35 m from the depths to top and the depths to bottom of the trenches listed on the OWS permit and/or obtained using a tile drain probe (Table 6B).

Conclusions

In the current study, CCR survey resistivity responses to groundwater specific conductivity were characterized by a strong inverse relationship between the background and drainfield resistivity and groundwater specific conductivity values at the sites with large OWS. The weaker inverse relationships between groundwater specific conductivity and corresponding resistivity values were present at the sites with small OWS. Success identifying the OWS wastewater inputs below the drainfield with CCR was limited at the sites with small OWS due to lower contrasts between background and drainfield groundwater specific conductivity. CCR surveys and inverse resistivity modeling tend to average out sharp resistivity contrasts that were commonly present along the perimeter of the drainfield. Therefore, resistivity data were more likely to detect groundwater quality changes associated with wastewater if they were conducted in the middle of the drainfield and the conductivity contrasts between drainfield and background groundwater conductivity was greater than 200 µS/cm.

The application of CCR surveys to locate a wastewater plume would be most efficient if collected during the initial stages of site instrumentation in order to determine the optimal areas for piezometer installation and subsequently best capture the wastewater plume. CCR survey resistivity values can be utilized in Archie's law to estimate expected pore water specific conductivity prior to site instrumentation and data collection.

Resistivity values collected less than 15 m downgradient of the OWS drainfield were decreased due to the increased conductivity associated with wastewater inputs. Researchers in the current study utilized CCR surveys completed by Smith (2013) to locate the wastewater plume downgradient of the drainfield and aid in the installation of piezometers downgradient of the school's drainfield. Future researchers could use CCR surveys to locate wastewater plumes prior to piezometer installation in order to best capture the plume core with distance from the drainfield. Surveys may be most effective during dry periods when the effects of dilution are minimized. During dry periods the resistivity response to contrasts in groundwater specific conductivity across background and drainfield locations may be more sensitive.

GPR 3D surveys and transects were successfully used to identify the active and deactivated drainfield trenches at the high school, drainfield trenches and distribution boxes at the elementary school, and drainfield trenches at the education center. At Residential 100 GPR 3D and 2D transects were used to identify the active and two deactivated drainfield trenches as well as a French drain. At Residential 100 the GPR 3D surveys and 2D transect (T4) were used to identify two low amplitude additional structures that were not shown on the OWS permit; due to the location of the structures at the residential site excavating to identify them was not permitted. The GPR data suggest that this technology would be effective at mapping active or inactive drainfields at sites where maps do not exist or location of the drainfield was unknown.

Future Research

Piezometer installation and site development can be time consuming and costly. The application of nonintrusive CCR surveys to locate a wastewater plume prior to piezometer installation would be helpful. CCR surveys could be incorporated into the initial site assessment strategy in order to determine the optimal locations for piezometer installation and maximize the efficiency of groundwater monitoring. CCR was successfully applied in the current study to locate wastewater influenced groundwater at sites in which the native media resistivity was elevated compared to the target resistivity media (> 200 µS/cm).

The locations of existing and de-activated OWS drainfields are often unclear. In some cases permits are lost, not drawn to scale or are illegible. GPR can accurately locate drainfield trenches in real time during surveys in the field. The current study had success using GPR at all sites to locate active and deactivated trenches at sites in which there was range of depth to water tables, OWS systems sizes, and types of trench media fill. The results indicate that GPR may be an effective tool utilized by public health departments, consulting firms, or other agencies interested in the effectiveness of septic systems. The application of GPR to locate the drainfield trenches and CCR to locate the wastewater plumes below the drainfield utilized in conjunction can reduce time spent in the field and aid in remediation efforts.

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Appendix A: OWS Permit Information

Table A1: Septic System Permit Information for the 7 research sites in the NCCP. Repaired systems including a replacement tank or drainfield trenches were indicated by *. The de-activated system at Residential 100 and the high school was discussed in the Methods. (WRRI, 2013 and DENR, 2011).

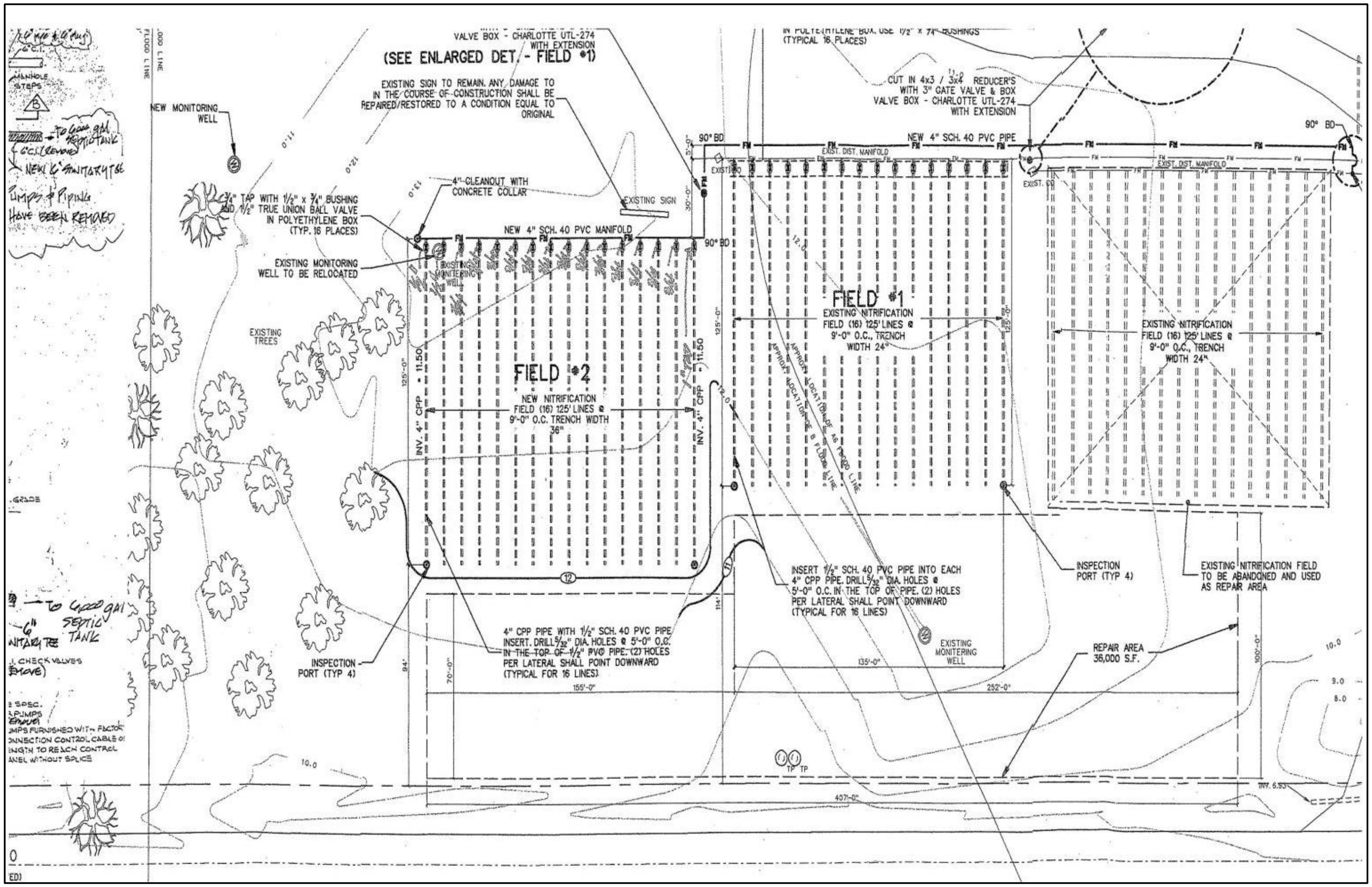
Site	System Installation Year	Tank Size (L)	Distribution Device	Max Design Flow (L/d)	Number of Drainfield Pipes	Drainfield Field Area (m^2)	Vertical Separation (m)
Residential 100	1998/2003*	3785	D-box	1360	6	155	≤0.1
Residential 200	1977/2004*	3785	D-box	1360	4	84	≥0.1
Residential 300	1986	3785	D-box	1360	4	111	≥0.1
Residential 400	1999	3785	D-box	1360	4	111	≥2
Elementary School	1987	37800	D-box (2)	37800	32	892	≥3
High School	pre-1999/1999*	73827	LPP (2)	73827	32	1115	≥1
Education Center	2012	3785	D-box	1512	3	59	≥3

Table A2: Septic System Permit Information regarding length, width, and thickness of OWS drainfield trenches listed on the permit for each OWS system. The cover was also listed in the table and refers to the thickness of sediment placed above the drainfield trench.

Site	**OWS Permit**			
	length (m)	width (m)	thickness (m)	cover (m)
High School	38	0.6, 0.9	0.3	0.6
Elementary School	30	0.9	0.3	0.7
Residential 100	20	0.9	0.3	0.15
Education Center	21	0.9	0.3	0.15

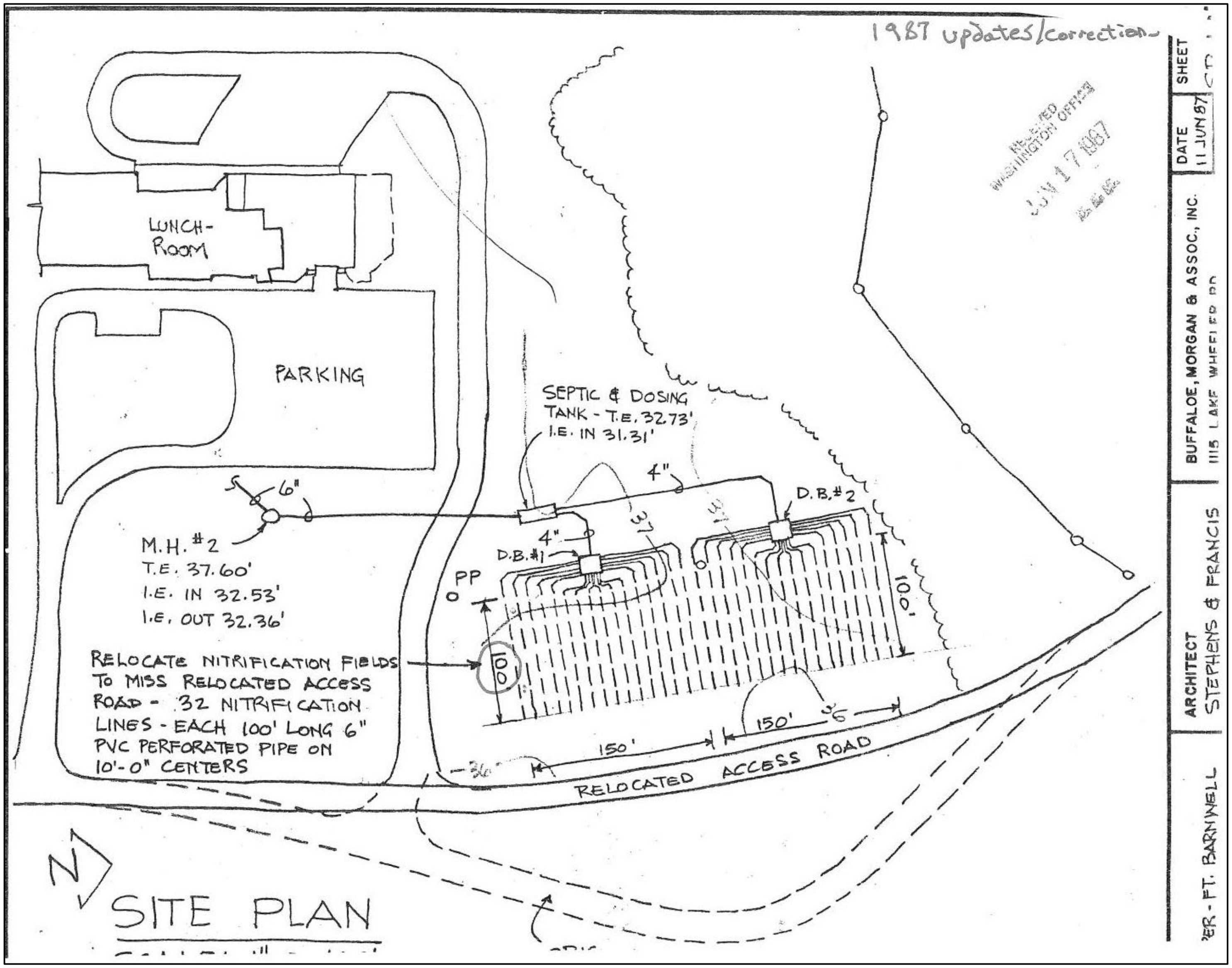
Appendix B: Copies of OWS Permits: the copies include visuals (mostly hand drawn) showing the locations of the OWS systems and system installation information

High School Permit



Appendix Figure B1: High School OWS permit

Elementary School Permit



Appendix Figure B2: Elementary School OWS permit

Education Center

PITT COUNTY PUBLIC HEALTH CENTER
Environmental Health Division
1717 W. 5th Street • Greenville, NC 27834

OPERATION PERMIT

Ground Absorption Sewage Disposal System
NC General Statutes Chapter 130A-Article 11

Owner: ATFS (education center)
Last / First / Middle

Location:

Type Use: Residence: ______ # Bedrooms: ______

Other: classroom w/40 seats H₂O Supply: Bell Arthur

System Type: IIC Review Freq.: ______

Tank Cap.: 1000 Mfgt.: Dellinger Serial #: STB-794

Sq. Ft.: 840* # Lines: 3 Width: EZ Flo Cover: 6"

Pump Tank Cap.: ______ Mfgt.: ______ Serial #: ______

Grease Trap Cap.: ______ Mfgt.: ______ Serial #: ______

Filter: Red PolyLoK Pump: ______

Comments: Installed 3 lines EZ Flo @ 70' each.

Installed by: ______

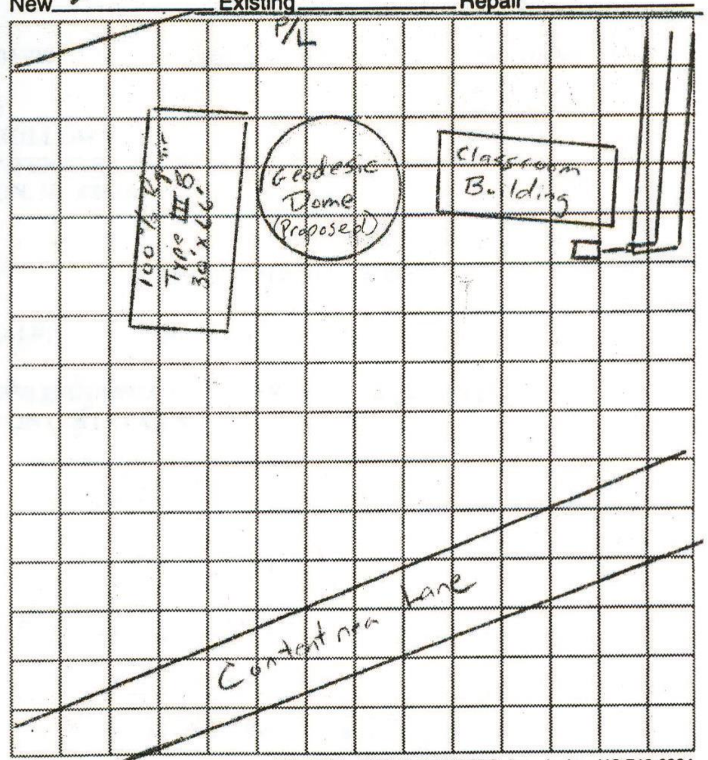
Inspected by: ______

PERMIT #: ______

Date Approved: 10/17/2011

Tax Parcel #: ______

New: ✓ Existing: ______ Repair: ______



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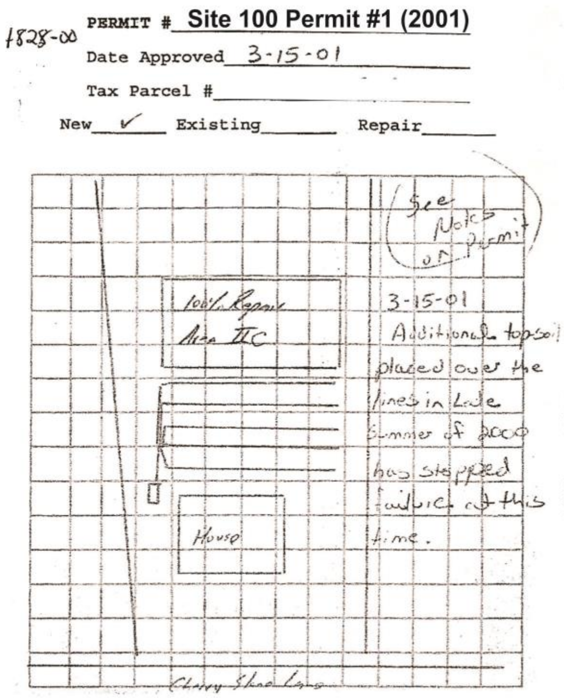
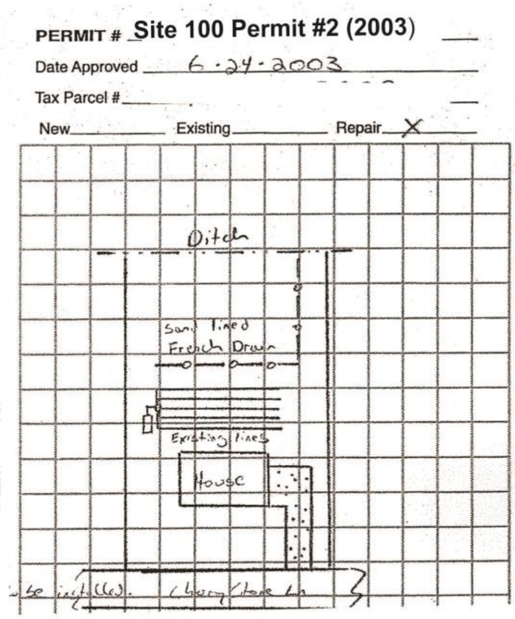
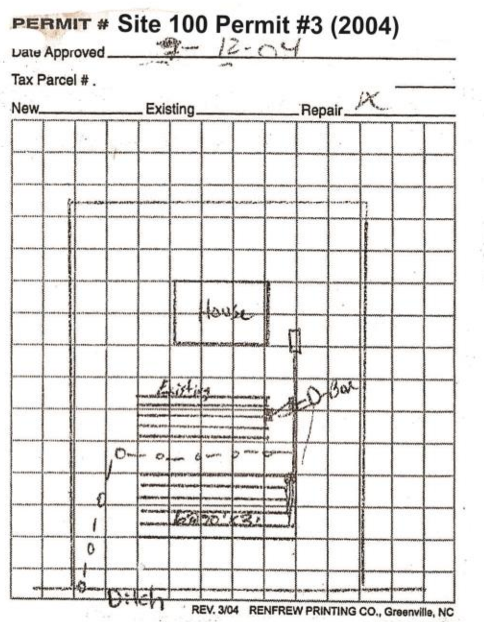
Appendices Figure B3: Education Center OWS permit

Residential 100







Appendix Figure B4 shows all 3 permits for Residential 100; the permits were numbered and dated. Note the range of sizes, scale, and location of the OWS system and differences in the property line and sizes of house visible between the 3 permits.

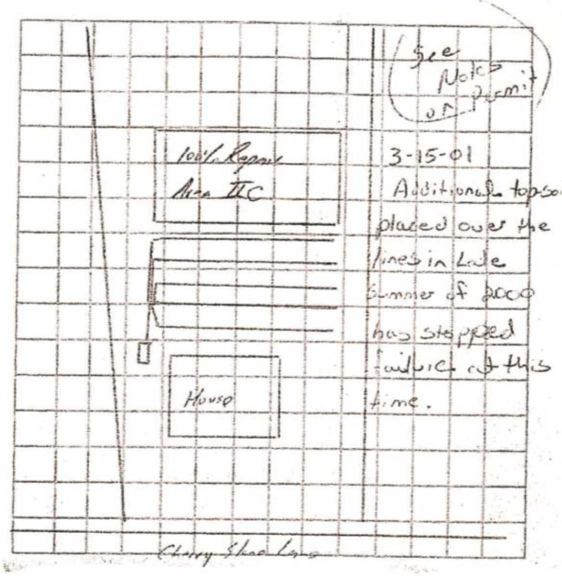
PITT COUNTY PUBLIC HEALTH CENTER
Environmental Health Division
1717 W. 5th St.
Greenville, NC 27834

OPERATION PERMIT
Ground Absorption Sewage Disposal System
NC General Statutes Chapter 130A-Article 11

Re: 14828-00

PERMIT #
Date Approved 3-15-01
Tax Parcel #
New ✓ Existing ____ Repair ____

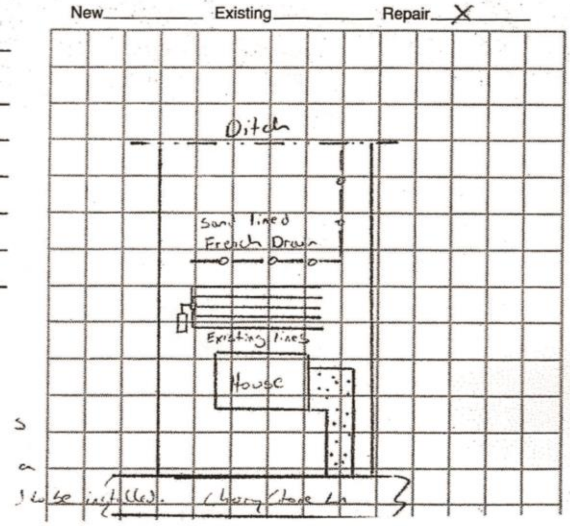
Owner Site 100 Permit #1 (2001)
Last First Middle
Location
Type Use: Residence ✓ # Bedrooms 4
Other
System Type: II C Review Freq.
Tank Cap. 1000 Mfgt. MST Serial # STB-787
Sq.Ft. 1200 # Lines 5 Width 3' Cover 6" cap



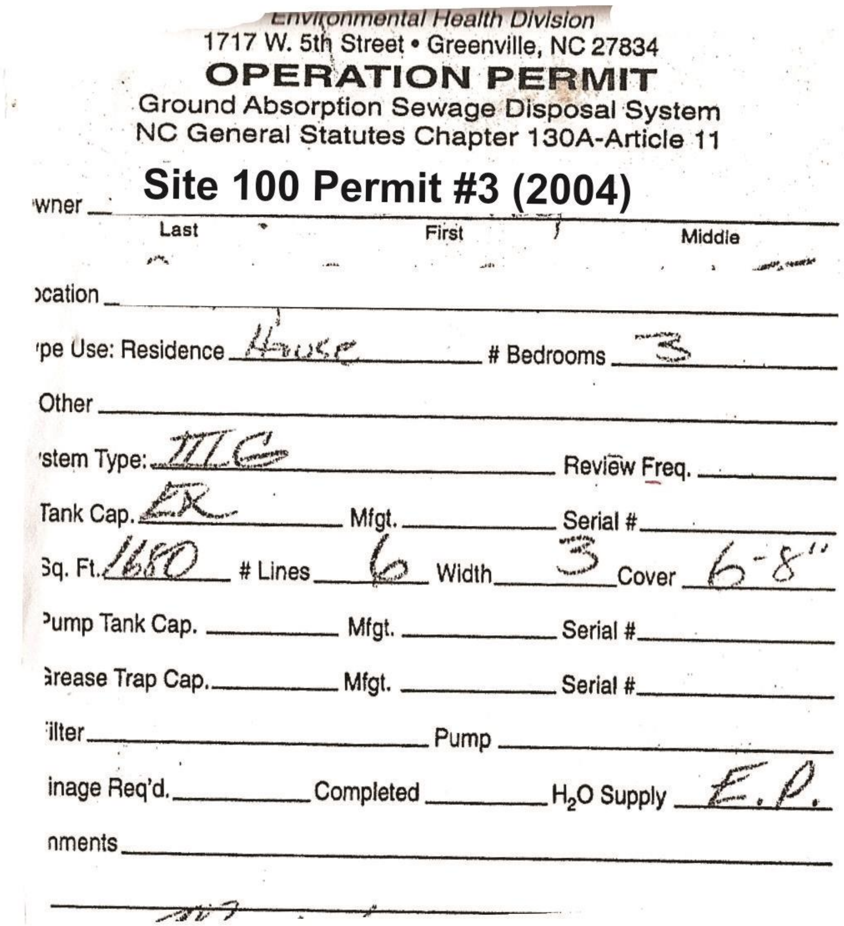
PITT COUNTY PUBLIC HEALTH CENTER
Environmental Health Division
1717 W. 5th St. • Greenville, NC 27834
OPERATION PERMIT
Ground Absorption Sewage Disposal System
NC General Statutes Chapter 130A-Article 11

PERMIT #
Date Approved 6-24-2003
Tax Parcel #
New ____ Existing ____ Repair X

Owner Site 100 Permit #2 (2003)
Last First Middle
Location
Type Use: Residence House # Bedrooms 3
Other
System Type: Existing Review Freq.
Tank Cap. 1000 exist Mfgt. — Serial # —
Sq.Ft. 1200 exist # Lines 5 Width 3' Cover 6"



Appendices Figure B5, shows OWS Permits 1 and 2 for Residential 100.



Environmental Health Division
1717 W. 5th Street • Greenville, NC 27834
OPERATION PERMIT
Ground Absorption Sewage Disposal System
NC General Statutes Chapter 130A-Article 11

Site 100 Permit #3 (2004)

wner ____ Last ____ First ____ Middle

cation ____

pe Use: Residence House ____ # Bedrooms 3

Other ____

stem Type: III G ____ Review Freq. ____

Tank Cap. EX ____ Mfgt. ____ Serial # ____

Sq. Ft. 1680 # Lines 6 Width 3 Cover 6-8"

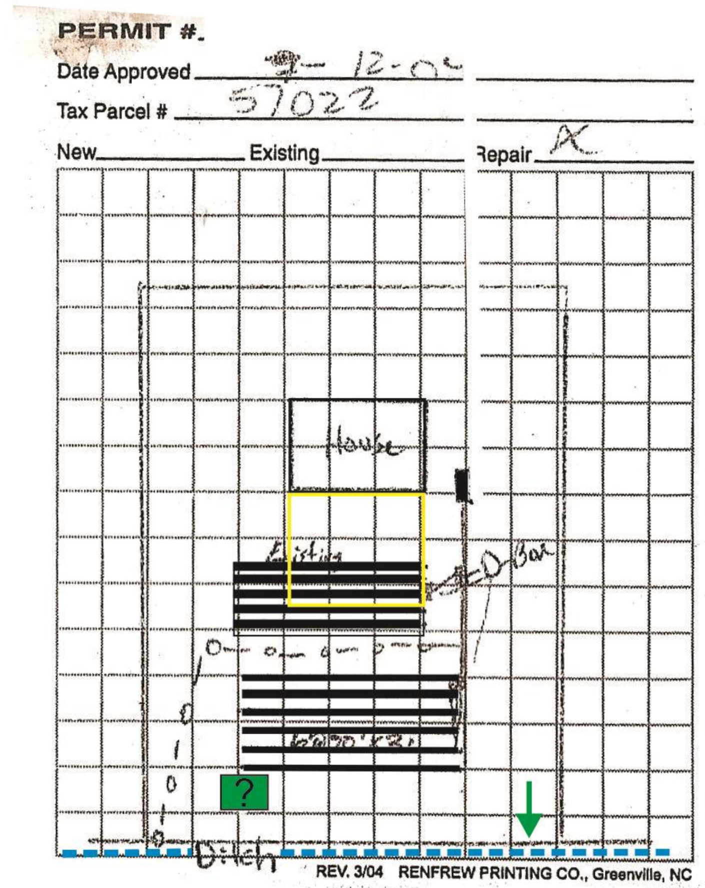
Pump Tank Cap. ____ Mfgt. ____ Serial # ____

Grease Trap Cap. ____ Mfgt. ____ Serial # ____

ilter ____ Pump ____

inage Req'd. ____ Completed ____ H_2O Supply E.P.

nments ____



Appendix Figure B6, shows Permit #3. The locations of the drainfield trenches (black lines), OWS tank (filled in black rectangle), unnamed stream (unnamed stream), and underground pipe (green arrow) were shown. The shed (the green filled square with the question mark) was not shown on the permit (Appendix Figure B4). The yellow square shows the approximate location of a deck and playground area that was fenced off.

Appendix C: Outline of field work completed and parameters used

Table C1. Outline of all sampling and methods used to assess water quality and the corresponding geophysical survey dates, transects IDs and surveys. * identifies CCR transects and 3D surveys that utilized the 10 m dipole lengths. GPR Transect 4 at Residential 100 was collected on 9/17/2012. The values collected were listed in Appendix F.

Site ID	Sampling Date	Method	Survey Date	ER Survey	GPR Survey
Education Center (ATFS)	3/23/2012	TLC Meter	3/23/2012	Transects 1-4	Transects 1-4
	9/4/2012	YSI 556 and CEL	9/4/2012	Transects 1-4	Transects 1-4
	11/30/2012	YSI 556 and CEL	11/30/2012	Transects 1-4, 5-6*	Transects 6
	4/17/2013	YSI 556 and CEL	4/17/2013	Transects 1*,2*	-
Residential 100	7/13/2012	YSI 556 and CEL	7/16/2012	3D and Transects 1,2,3	3D
	11/16/2012	YSI 556 and CEL	11/16/2012	*Transects 1-3	Transects 1,2,3
	3/27/2013	YSI 556 and CEL	3/27/2013	3D and Transect 1,2,3	3D and Transects 1-3
High School (WCHS)	9/7/2012	YSI 556 and CEL	9/7/2012	1-6 Transects	Transects 1-6
	11/14/2012	YSI 556 and CEL	11/14/2012	*3D, Transect	3D, Transect 1
	4/10/2013	YSI 556 and CEL	4/10/2013	3D, Transect 1	3D
Elementary School (JWSES)	9/10/2012	YSI 556 and CEL	9/10/2012	Transects 1-6	Transects 1-6
	11/14/2012	YSI 556 and CEL	11/19/2012	*3D, Transect 1	3D, Transect 1
	3/25/2013	YSI 556 and CEL	3/25/2013	3D, Transect 1	3D, Transect 1
Residential 200	9/17/2012	YSI 556 and CEL	4/15/2012	Transect 1	Transect 1
Residential 300	9/17/2012	YSI 556 and CEL	4/15/2012	Transect 1	Transect 1
Residential 400	9/17/2012	YSI 556	4/15/2012	Transect 1	Transect 1

Appendix C

Table C2. The parameters above were analyzed at the CEL (Appendix B1) at East Carolina University using corresponding SmartChem 200 EPA approved analytical methods listed. Research by Smith, 2013 applied the same methods to test for the listed parameters.

Water Quality Parameters Tested	Corresponding EPA Approved Analytical Method
DKN	390-200
NH4	210-201B
NO3+NO2	375-100E-1
Cl	231N-0406C
PO4	410-3651

Table C3.Parameters for 3D geophysical survey conducted in the study and listed in Appendix C1. The survey areas were shown in map view in Appendix H.

Site	3D Survey Area	CCR Line Spacing	GPR Line Spacing
Residential 100	20m x 35m	2	1
Elementary School	48 m x 70 m	4	2
High School	48 m x 125 m	4	2

Table C4. Geophysical transect IDs for each site, with corresponding transect lengths, and mark points used for CCR surveys transects. The map views of transects were shown in Appendix H.

Site ID	Transect ID	Length of Transect (m)	Mark (m)
High School (WCHS)	1	300	50
	2	200	50
	3	200	50
	4	70	35
	5	70	35
	6	100	50
Elementary School (JWSES)	1	175	25
	2	100	25
	3	75	25
	4	75	25
	5	150	50
	6	75	25
Education Center (ATFS)	1	100	25
	2	75	25
	3	70	10
	4	40	10
	5	30	10
	6	40	20
Residential 100	1	60	20
	2	40	20
	3	40	20
	4	40	20
Residential 200	1	30	15
Residential 300	1	50	25
	2	25	12.5
Residential 400	1	50	25

Appendix D: CERL (laboratory) Water Quality Data

Table D1, shows the water quality data parameters assessed in the CEL laboratory at ECU. The parameters include: NH_4, NO_3+NO_2, DKN, TDN, Cl, and PO_4 and were organized based on the site the data were collected from and location of the piezometer at the site. The locations of the piezometer the samples were collected from included: BG (background), DF (drainfield), DG (downgradient) and OSP (outside the drainfield flow path). The tank or distribution box (Tank) and surficial water (SW) sources were labeled. The type of sample was listed as: DW (drinking water), GW (groundwater) or SW (surface water). The distance from the drainfield was provided for "DG" piezometers and surface water bodies. Duplicate sample analyzed were marked by "dup". The parameter values < a set number were less than the detection limit set during laboratory analysis.

High School (Site: HS)

Date	Site	Sample ID	NH_4-N (mg/L)	NO_3-N +NO_2 (mg/L)	DKN (mg/L)	TDN (mg/L)	Cl (mg/L)	PO_4-P (mg/L)	Location of piezometer	Distance From DF (m)	Sample Type
11/14/2012	HS	DW	0.30	<0.008	0.07	0.07	21.79	1.22	DW	-	DW
9/7/2012	HS	1s	0.04	<0.008	0.74	0.74	16.29	<0.0015	BG	-	GW
9/7/2012	HS	1s dup	0.04	<0.008	0.77	0.77	16.99	<0.0015	BG	-	GW
11/14/2012	HS	1s	4.22	<0.008	4.09	4.09	38.97	<0.0015	BG	-	GW
4/10/2013	HS	1d	5.93	0.05	4.55	4.61	90.03	<0.008	BG	-	GW
4/10/2013	HS	1s	0.26	0.03	0.31	0.34	7.73	<0.008	BG	-	GW
9/7/2012	HS	2	0.06	0.11	0.76	0.87	9.40	0.09	BG	-	GW
4/10/2013	HS	2	0.59	0.02	1.21	1.23	26.99	0.27	BG	-	GW
9/7/2012	HS	3	0.12	0.09	0.63	0.73	2.25	0.02	BG	-	GW
9/7/2012	HS	3 dup	0.11	0.10	no sample	0.10	2.42	0.02	BG	-	GW
4/10/2013	HS	3	1.44	0.09	0.18	0.26	2.54	<0.008	BG	-	GW
9/7/2012	HS	4	0.03	0.07	0.74	0.81	2.27	0.28	BG	-	GW
9/7/2012	HS	5d	0.06	0.06	0.38	0.43	2.62	0.00	BG	-	GW
9/7/2012	HS	5s	0.03	0.22	0.40	0.62	3.70	0.00	BG	-	GW

11/14/2012	HS	5s	0.09	0.47	0.30	0.77	3.82	<0.0015	BG	-	GW
4/10/2013	HS	5d	2.93	0.18	0.21	0.39	3.58	<0.008	BG	-	GW
4/10/2013	HS	5d-dup	3.15	0.17	0.22	0.39	3.82	<0.008	BG	-	GW
9/7/2012	HS	6	0.13	0.05	0.52	0.58	3.21	0.05	BG	-	GW
11/14/2012	HS	6	0.17	0.10	0.19	0.29	6.49	<0.0015	BG	-	GW
4/10/2013	HS	6	3.37	0.01	0.19	0.20	7.31	0.02	BG	-	GW
9/7/2012	HS	7	0.03	0.01	0.42	0.43	4.11	0.01	BG	-	GW
11/14/2012	HS	7	0.35	0.03	0.22	0.25	1.95	0.01	BG	-	GW
4/10/2013	HS	7	3.02	0.14	0.09	0.23	2.08	<0.008	BG	-	GW
9/7/2012	HS	14	0.24	0.08	0.57	0.65	1.42	0.05	BG	-	GW
11/14/2012	HS	14	0.09	0.15	0.30	0.45	1.51	0.04	BG	-	GW
4/10/2013	HS	14	0.81	0.07	0.10	0.18	1.31	0.01	BG	-	GW
9/7/2012	HS	8	0.03	2.88	0.36	3.24	4.88	0.01	DF	-	GW
11/14/2012	HS	8	0.83	20.32	0.30	20.62	20.15	0.00	DF	-	GW
4/10/2013	HS	8	1.77	3.98	0.25	4.23	6.53	<0.008	DF	-	GW
9/7/2012	HS	9	0.03	0.28	0.36	0.64	1.44	0.01	DF	-	GW
11/14/2012	HS	9	0.32	0.63	0.29	0.92	1.77	0.04	DF	-	GW
4/10/2013	HS	9	0.07	2.14	0.22	2.37	2.81	0.01	DF	-	GW
9/7/2012	HS	11	0.04	0.01	0.36	0.37	1.80	<0.0015	DF	-	GW
11/14/2012	HS	11	0.54	0.16	0.74	0.90	2.14	0.00	DF	-	GW
4/10/2013	HS	11	0.17	0.88	0.13	1.01	2.64	0.01	DF	-	GW
9/7/2012	HS	12	0.08	7.78	0.70	8.48	8.43	0.01	DF	-	GW
11/14/2012	HS	12	0.08	4.89	0.37	5.26	10.93	0.01	DF	-	GW
4/10/2013	HS	12	0.14	34.50	0.22	34.72	42.67	<0.008	DF	-	GW
9/7/2012	HS	13d	0.01	38.43	0.73	39.16	47.40	<0.0015	DF	-	GW
9/7/2012	HS	13s	0.03	5.32	0.59	5.91	13.43	0.01	DF	-	GW
11/14/2012	HS	13d	0.13	59.37	0.78	60.16	67.61	0.01	DF	-	GW
11/14/2012	HS	13s	0.42	30.26	0.90	31.16	38.57	0.18	DF	-	GW

4/10/2013	HS	13d	0.19	77.49	0.51	78.00	88.87	<0.008	DF	-	GW
4/10/2013	HS	13s	0.37	50.20	0.44	50.64	63.32	0.02	DF	-	GW
9/7/2012	HS	15	0.03	1.38	0.44	1.82	6.35	0.12	DF	-	GW
11/14/2012	HS	15	0.05	6.73	0.59	7.32	8.43	0.36	DF	-	GW
4/10/2013	HS	15	1.16	49.47	0.82	50.29	54.34	0.32	DF	-	GW
9/7/2012	HS	16	0.05	0.20	0.24	0.44	2.18	<0.0015	DF	-	GW
11/14/2012	HS	16	0.14	4.12	0.42	4.54	8.21	0.02	DF	-	GW
4/10/2013	HS	16	1.32	43.64	0.15	43.79	48.03	0.01	DF	-	GW
9/7/2012	HS	17	0.02	11.60	0.37	11.96	8.43	0.04	DF	-	GW
11/14/2012	HS	17	0.13	80.09	0.35	80.44	109.34	0.25	DF	-	GW
4/10/2013	HS	17	1.41	90.84	0.17	91.00	-	0.01	DF	-	GW
9/7/2012	HS	18	0.02	2.77	0.60	3.37	4.29	0.22	DF	-	GW
11/14/2012	HS	18	0.18	28.47	0.54	29.01	32.97	0.22	DF	-	GW
4/10/2013	HS	18	1.24	31.97	0.50	32.47	47.43	0.20	DF	-	GW
9/7/2012	HS	24d	0.05	5.44	0.45	5.89	23.12	<0.0015	DF	-	GW
9/7/2012	HS	24s	0.02	2.00	0.47	2.48	7.45	<0.0015	DF	-	GW
11/14/2012	HS	24d	0.15	18.56	0.61	19.17	35.95	0.00	DF	-	GW
11/14/2012	HS	24s	0.08	5.24	0.53	5.77	9.01	0.01	DF	-	GW
4/10/2013	HS	24d	0.25	35.48	0.32	35.80	46.75	<0.008	DF	-	GW
4/10/2013	HS	24s	0.29	22.02	0.53	22.55	25.86	0.01	DF	-	GW
9/7/2012	HS	25d	0.06	9.53	0.51	10.04	23.85	<0.0015	DG	3	GW
9/7/2012	HS	25m	0.01	0.16	0.67	0.83	2.76	0.13	DG	3	GW
9/7/2012	HS	25m dup	0.03	0.13	0.84	0.96	2.27	0.13	DG	3	GW
9/7/2012	HS	25s	0.73	0.02	2.79	2.81	9.61	3.43	DG	3	GW
11/14/2012	HS	25d	0.11	11.03	0.56	11.59	24.89	<0.0015	DG	3	GW
11/14/2012	HS	25m	0.06	1.13	0.43	1.56	3.99	0.26	DG	3	GW
11/14/2012	HS	25s	0.75	0.44	1.44	1.88	4.65	0.05	DG	3	GW
4/10/2013	HS	25d	0.38	27.70	0.51	28.21	35.32	0.02	DG	3	GW

4/10/2013	HS	25m	0.09	0.74	0.33	1.06	2.38	0.17	DG	3	GW
4/10/2013	HS	25s	0.18	1.27	0.87	2.15	4.24	0.04	DG	3	GW
9/7/2012	HS	26d	0.36	0.01	0.30	0.31	11.21	<0.0015	DG	10	GW
9/7/2012	HS	26s	<0.012	0.13	0.07	0.20	2.26	<0.0015	DG	10	GW
11/14/2012	HS	26d	0.18	0.95	0.29	1.24	7.26	0.01	DG	10	GW
11/14/2012	HS	26s	0.18	0.19	0.14	0.33	2.46	<0.0015	DG	10	GW
4/10/2013	HS	26d	0.68	2.11	0.11	2.22	5.15	<0.008	DG	10	GW
4/10/2013	HS	26s	0.61	0.06	0.20	0.26	1.66	<0.008	DG	10	GW
9/7/2012	HS	20	<0.012	0.06	0.17	0.24	1.58	0.02	DG	22	GW
11/14/2012	HS	20	0.27	0.06	0.19	0.25	1.16	0.01	DG	22	GW
4/10/2013	HS	20	0.22	0.08	0.17	0.25	1.58	0.01	DG	22	GW
9/7/2012	HS	21	0.11	0.04	0.83	0.87	3.14	0.00	DG	41	GW
11/14/2012	HS	21	0.07	0.09	0.75	0.84	3.99	0.04	DG	41	GW
4/10/2013	HS	21	0.12	0.04	0.39	0.43	1.62	0.01	DG	41	GW
9/7/2012	HS	22d	0.94	0.94	1.16	2.10	1.94	0.04	DG	88	GW
9/7/2012	HS	22s	0.09	0.21	0.32	0.53	1.01	0.01	DG	88	GW
11/14/2012	HS	22d	0.09	0.76	0.21	0.97	1.93	<0.0015	DG	88	GW
11/14/2012	HS	22s	0.22	0.01	0.36	0.37	2.12	0.00	DG	88	GW
4/10/2013	HS	22d	0.11	0.43	0.08	0.52	1.38	<0.008	DG	88	GW
4/10/2013	HS	22s	0.14	0.02	0.07	0.10	0.87	0.01	DG	88	GW
9/7/2012	HS	23	0.05	0.02	0.45	0.47	0.94	<0.0015	DG	145	GW
11/14/2012	HS	23	0.54	1.28	0.41	1.70	1.18	0.06	DG	145	GW
4/10/2013	HS	23	0.17	0.14	0.37	0.51	0.77	0.01	DG	145	GW
9/7/2012	HS	19	0.04	0.12	0.37	0.49	4.03	0.08	OSP	23	GW
11/14/2012	HS	19	0.47	0.10	0.26	0.36	3.29	0.01	OSP	23	GW
4/10/2013	HS	19	0.59	1.56	0.15	1.72	2.25	0.01	OSP	23	GW
9/7/2012	HS	10	0.08	0.16	0.50	0.66	1.06	0.02	OSP	-	GW
4/10/2013	HS	10	0.14	0.16	0.11	0.27	1.29	<0.008	OSP	-	GW

9/7/2012	HS	27d	0.47	2.39	0.75	3.14	4.29	0.15	OSP	-	GW
9/7/2012	HS	27m	0.06	0.12	0.60	0.72	1.83	0.29	OSP	-	GW
9/7/2012	HS	27s	0.07	<0.008	0.23	0.23	1.93	<0.0015	OSP	-	GW
11/14/2012	HS	27d	0.34	3.34	0.82	4.17	8.69	0.68	OSP	-	GW
11/14/2012	HS	27d dup	0.36	3.32	0.81	4.12	9.42	0.68	OSP	-	GW
11/14/2012	HS	27m	0.29	0.13	0.41	0.54	4.42	<0.0015	OSP	-	GW
11/14/2012	HS	27s	0.13	0.11	0.26	0.37	1.88	<0.0015	OSP	-	GW
4/10/2013	HS	27d	0.91	41.85	0.52	42.37	48.02	0.17	OSP	-	GW
4/10/2013	HS	27m	0.79	0.75	0.17	0.92	4.82	<0.008	OSP	-	GW
4/10/2013	HS	27s	0.71	0.12	0.11	0.24	0.73	<0.008	OSP	-	GW
4/10/2013	HS	ditch	0.09	0.31	0.54	0.85	5.64	<0.008	DG	162	SW
9/7/2012	HS	Tank	101.84	<0.008	105.38	105.38	99.65	7.13	Tank	-	Tank
11/14/2012	HS	Tank	75.23	0.03	83.24	83.27	121.95	11.80	Tank	-	Tank
4/10/2013	HS	Tank	51.82	0.04	53.79	53.83	98.11	7.66	Tank	-	Tank

Elementary School (Site: ES)

Date	Site	Sample ID	NH_4-N (mg/L)	NO_3-N $+NO_2$ (mg/L)	DKN (mg/L)	TDN (mg/L)	Cl (mg/L)	PO_4-P (mg/L)	Location of piezometer	Distance From DF (m)	Sample Type
11/14/2012	ES	DW	0.06	<0.008	0.99	0.99	31.16	0.55	DW		DW
11/14/2012	ES	1	0.18	0.31	0.70	1.00	2.71	0.59	BG	-	GW
11/14/2012	ES	1	0.72	0.05	1.09	1.14	5.97	0.01	BG	-	GW
9/10/2012	ES	2	<0.012	1.96	0.32	2.28	5.40	0.02	BG	-	GW
11/14/2012	ES	2	0.33	2.28	0.36	2.64	4.30	<0.0015	BG	-	GW
3/25/2013	ES	2	0.14	1.99	0.22	2.22	3.90	0.03	BG	-	GW
9/10/2012	ES	3	0.26	0.07	0.48	0.55	6.52	0.02	BG	-	GW

11/14/2012	ES	3	0.17	0.42	0.20	0.62	2.53	0.04	BG	-	GW
3/25/2013	ES	3	0.16	0.56	0.15	0.71	3.58	0.02	BG	-	GW
9/10/2012	ES	9	0.01	0.26	0.14	0.39	1.65	0.06	BG	-	GW
11/14/2012	ES	9	0.09	0.66	0.11	0.77	1.95	0.08	BG	-	GW
3/25/2013	ES	9	0.55	0.16	0.11	0.27	2.07	0.07	BG	-	GW
9/10/2012	ES	4	<0.012	14.23	0.35	14.58	24.30	2.08	DF	-	GW
11/14/2012	ES	4	0.15	17.32	0.30	17.61	33.29	0.03	DF	-	GW
3/25/2013	ES	4	0.12	35.43	0.42	35.85	70.69	0.58	DF	-	GW
9/10/2012	ES	5	0.03	30.29	0.69	30.98	64.02	0.44	DF	-	GW
11/14/2012	ES	5	0.11	21.42	0.32	21.74	62.19	0.18	DF	-	GW
3/25/2013	ES	5	0.23	23.61	0.24	23.85	82.28	0.12	DF	-	GW
9/10/2012	ES	6	<0.012	45.72	0.46	46.19	71.56	0.15	DF	-	GW
11/14/2012	ES	6	0.15	33.72	0.36	34.07	57.20	0.07	DF	-	GW
3/25/2013	ES	6	0.31	52.48	0.27	52.75	85.19	0.16	DF	-	GW
9/10/2012	ES	7	0.14	59.51	0.87	60.38	70.62	0.44	DF	-	GW
11/14/2012	ES	7	0.19	5.83	0.39	6.22	88.22	0.07	DF	-	GW
11/14/2012	ES	7	0.14	3.04	0.28	3.33	87.28	0.05	DF	-	GW
3/25/2013	ES	7	0.41	0.31	0.38	0.69	75.17	0.08	DF	-	GW
9/10/2012	ES	10	<0.012	30.35	0.55	30.90	40.45	2.20	DF	-	GW
11/14/2012	ES	10	0.11	31.68	0.38	32.06	62.31	0.12	DF	-	GW
3/25/2013	ES	10	0.35	44.25	0.24	44.49	87.30	0.50	DF	-	GW
9/10/2012	ES	14	0.02	25.42	0.32	25.74	71.86	0.09	DF	-	GW
11/14/2012	ES	14	0.10	25.15	0.23	25.38	68.02	0.04	DF	-	GW
3/25/2013	ES	14	0.09	29.47	0.17	29.64	77.61	0.14	DF	-	GW
9/10/2012	ES	11d	0.28	0.59	0.56	1.14	11.16	0.81	DF	-	GW
11/14/2012	ES	11d	0.46	0.38	0.27	0.65	8.02	1.07	DF	-	GW
3/25/2013	ES	11d	0.09	0.44	0.08	0.53	7.74	0.46	DF	-	GW
9/10/2012	ES	11s	0.09	0.14	0.29	0.43	8.18	0.30	DF	-	GW

11/14/2012	ES	11s	0.14	1.25	0.36	1.61	7.84	0.26	DF	-	GW
3/25/2013	ES	11s	0.38	0.04	<0.06	0.04	5.91	0.16	DF	-	GW
9/10/2012	ES	13d	0.35	15.32	1.45	16.77	25.55	0.08	DF	-	GW
11/14/2012	ES	13d	0.31	39.67	<0.06	39.67	66.87	0.05	DF	-	GW
3/25/2013	ES	13d	0.14	30.06	0.23	30.30	46.67	0.12	DF	-	GW
9/10/2012	ES	13s	0.03	30.71	0.69	31.40	51.24	0.35	DF	-	GW
11/14/2012	ES	13s	0.09	24.48	0.58	25.06	39.85	0.31	DF	-	GW
3/25/2013	ES	13s	0.08	34.51	0.23	34.74	59.31	0.19	DF	-	GW
9/10/2012	ES	12d	0.30	0.12	0.57	0.69	44.62	1.05	DG	2	GW
11/14/2012	ES	12d	0.21	0.19	0.22	0.40	40.20	0.76	DG	2	GW
3/25/2013	ES	12d	0.09	0.06	0.13	0.18	42.44	0.38	DG	2	GW
9/10/2012	ES	12s	0.14	10.29	0.43	10.72	28.18	0.01	DG	2	GW
9/10/2012	ES	16	0.04	0.03	0.19	0.22	6.02	0.03	DG	34	GW
11/14/2012	ES	16	0.09	0.07	0.08	0.15	7.21	0.16	DG	34	GW
3/25/2013	ES	16	0.15	0.10	<0.06	0.10	7.25	0.23	DG	34	GW
9/10/2012	ES	17	0.41	0.03	0.69	0.72	43.12	0.01	DG	36	GW
11/14/2012	ES	17	0.42	<0.008	0.59	0.59	32.67	0.01	DG	36	GW
3/25/2013	ES	17	0.22	1.31	0.12	1.43	22.80	0.02	DG	36	GW
9/10/2012	ES	18	<0.012	7.32	0.30	7.62	38.06	0.11	DG	37	GW
11/14/2012	ES	18	0.11	8.84	0.16	9.00	33.04	0.01	DG	37	GW
3/25/2013	ES	18	0.25	7.00	0.08	7.08	26.94	<0.008	DG	37	GW
9/10/2012	ES	20	1.09	0.09	1.57	1.67	22.25	0.19	DG	51	GW
11/14/2012	ES	20	0.79	<0.008	1.19	1.19	21.26	0.03	DG	51	GW
3/25/2013	ES	20	0.40	0.03	0.56	0.59	18.23	0.16	DG	51	GW
11/14/2012	ES	19	1.80	<0.008	2.28	2.28	11.54	<0.0015	DG	54	GW
3/25/2013	ES	19	1.18	<0.008	1.50	1.50	12.50	0.03	DG	54	GW
11/14/2012	ES	21	0.10	1.52	0.24	1.75	11.96	0.12	DG	72	GW
9/10/2012	ES	15	0.06	0.79	0.44	1.23	2.28	0.13	OSP	26	GW

11/14/2012	ES	15	0.77	0.35	1.05	1.40	4.22	<0.0015	OSP	26	GW
3/25/2013	ES	15	0.10	0.28	0.42	0.70	5.95	0.33	OSP	26	GW
9/10/2012	ES	8	<0.012	16.31	0.37	16.68	71.35	0.07	OSP	-	GW
11/14/2012	ES	8	0.07	14.23	0.37	14.60	63.77	0.03	OSP	-	GW
3/25/2013	ES	8	0.42	13.76	0.13	13.89	56.29	<0.008	OSP	-	GW
9/10/2012	ES	Spring 1	<0.012	13.28	0.17	13.45	38.30	0.22	DG	38	SW
11/14/2012	ES	Spring 1	0.09	7.56	0.09	7.65	28.26	0.21	DG	38	SW
3/25/2013	ES	Spring 1	0.33	7.64	<0.06	7.64	26.01	0.23	DG	38	SW
9/10/2012	ES	Spring 1-dup	<0.012	14.25	0.13	14.38	40.41	0.22	DG	38	SW
9/10/2012	ES	Spring 2	<0.012	13.43	0.17	13.60	38.71	0.18	DG	43	SW
3/25/2013	ES	Spring 2	0.39	6.50	<0.06	6.50	6.10	0.14	DG	43	SW
9/10/2012	ES	5m upstream	0.02	1.01	0.26	1.27	9.84	0.06	DG	51	SW
11/14/2012	ES	5m upstream	0.12	1.93	0.16	2.09	8.45	0.13	DG	51	SW
3/25/2013	ES	5m upstream	0.52	2.24	0.14	2.37	7.94	0.05	DG	51	SW
9/10/2012	ES	spring/stream	<0.012	5.51	0.14	5.64	16.97	0.12	DG	52	SW
11/14/2012	ES	spring/stream	0.11	1.85	0.11	1.95	8.76	0.06	DG	52	SW
3/25/2013	ES	spring/stream	0.40	7.50	0.06	7.56	28.02	0.20	DG	52	SW
9/10/2012	ES	5m downstream	0.03	2.36	0.33	2.69	12.39	0.07	DG	54	SW

11/14/2012	ES	5m downstream	0.11	2.05	0.14	2.19	9.01	0.09	DG	54	SW
3/25/2013	ES	5m downstream	0.53	2.26	0.16	2.41	8.81	0.05	DG	54	SW
9/10/2012	ES	Tank/D-Box	27.97	0.03	26.61	26.64	28.50	3.79	Tank	-	Tank
11/14/2012	ES	Tank/D-Box	5.07	1.32	1.21	2.53	21.71	0.33	Tank	-	Tank
3/25/2013	ES	Tank/D-Box	41.57	0.07	55.67	55.74	132.46	11.30	Tank	-	Tank

Education Center (Site: EC)

Date	Site	Sample ID	NH_4-N (mg/L)	NO_3-N +NO_2 (mg/L)	DKN (mg/L)	TDN (mg/L)	Cl (mg/L)	PO_4-P (mg/L)	Location of piezometer	Distance From DF (m)	Sample Type
4/17/2013	EC	1d	0.24	0.04	0.94	0.98	2.03	0.34	BG	-	GW
11/29/2012	EC	1d	0.08	0.17	0.35	0.53	5.57	0.61	BG	-	GW
9/4/2012	EC	1d	0.03	<0.008	1.65	1.65	16.58	4.49	BG	-	GW
4/17/2013	EC	1s	0.17	4.10	0.12	4.22	6.69	<0.008	BG	-	GW
11/29/2012	EC	1s	0.20	2.62	0.40	3.02	9.80	<0.015	BG	-	GW
9/4/2012	EC	1s	0.02	0.07	0.50	0.56	19.38	0.03	BG	-	GW
4/17/2013	EC	2d	0.23	3.85	0.23	4.07	7.63	<0.008	DF	-	GW
11/29/2012	EC	2d	0.22	5.18	0.12	5.30	10.31	0.02	DF	-	GW
9/4/2012	EC	2d	0.05	0.27	0.54	0.81	6.42	1.22	DF	-	GW
4/17/2013	EC	2s	0.16	6.05	0.23	6.28	9.86	<0.008	DF	-	GW
11/29/2012	EC	2s	1.07	6.21	1.32	7.53	12.72	<0.015	DF	-	GW
9/4/2012	EC	2s	<0.012	3.82	0.41	4.23	28.83	<0.0015	DF	-	GW
4/17/2013	EC	3	0.25	4.17	0.13	4.30	6.91	0.01	DF	-	GW

11/29/2012	EC	3	6.46	0.17	6.30	6.48	8.91	0.16	DF	-	GW
9/4/2012	EC	3	0.26	0.04	0.98	1.02	5.98	1.94	DF	-	GW
4/17/2013	EC	4	0.41	1.73	0.43	2.16	6.94	0.04	DG	4	GW
11/29/2012	EC	4	3.30	0.87	2.89	3.77	11.84	0.18	DG	4	GW
9/4/2012	EC	4	0.05	0.05	1.47	1.51	4.30	5.13	DG	4	GW
4/17/2013	EC	5	0.39	6.07	0.21	6.28	8.75	<0.008	DG	7	GW
11/29/2012	EC	5	0.25	6.80	0.40	7.20	12.37	0.03	DG	7	GW
9/4/2012	EC	5	1.44	5.31	1.95	7.26	9.15	0.06	DG	7	GW
4/17/2013	EC	6	0.52	0.25	0.13	0.39	38.84	<0.008	DG	39	GW
11/29/2012	EC	6	0.18	0.12	0.28	0.40	51.36	<0.015	DG	39	GW
9/4/2012	EC	6	0.36	0.17	0.97	1.14	9.30	0.01	DG	39	GW
9/4/2012	EC	6- dup	0.18	0.47	0.61	1.08	9.61	0.00	DG	39	GW
4/17/2013	EC	7	3.84	0.21	2.71	2.91	19.21	<0.008	DG	36	GW
11/29/2012	EC	7	2.96	0.24	2.97	3.21	30.47	<0.015	DG	36	GW
9/4/2012	EC	7	0.29	0.49	0.51	1.00	22.08	0.01	DG	36	GW
4/17/2013	EC	8	0.64	1.79	0.13	1.92	7.53	<0.008	DG	35	GW
11/29/2012	EC	8	0.45	2.22	0.50	2.72	13.10	<0.015	DG	35	GW
9/4/2012	EC	8	0.06	3.73	0.24	3.97	16.17	<0.0015	DG	35	GW
4/17/2013	EC	9	0.69	0.95	0.10	1.05	7.64	<0.008	DG	39	GW
11/29/2012	EC	9	0.13	0.85	0.23	1.08	11.05	0.01	DG	39	GW
9/4/2012	EC	9	0.39	0.20	0.74	0.94	5.26	0.03	DG	39	GW
11/29/2012	EC	10	0.09	3.30	0.18	3.49	8.92	<0.015	DG	21	GW
9/4/2012	EC	10	0.03	4.68	0.20	4.89	10.08	0.00	DG	21	GW
4/17/2013	EC	11d	1.25	5.19	0.15	5.34	7.69	0.05	DG	19	GW
11/29/2012	EC	11d	0.07	5.30	0.12	5.42	9.21	0.14	DG	19	GW
9/4/2012	EC	11d	0.03	5.18	0.15	5.34	9.23	0.04	DG	19	GW
4/17/2013	EC	11s	0.83	4.14	0.06	4.20	7.84	0.02	DG	19	GW
11/29/2012	EC	11s	0.06	6.04	0.11	6.15	8.09	0.02	DG	19	GW

9/4/2012	EC	11s	0.02	4.83	0.14	4.98	6.96	0.01	DG	19	GW
4/17/2013	EC	12d	0.75	4.69	0.19	4.88	8.73	0.02	DG	23	GW
11/29/2012	EC	12d	0.51	3.26	0.21	3.47	10.25	0.01	DG	23	GW
9/4/2012	EC	12d	0.04	5.72	0.39	6.10	11.48	0.01	DG	23	GW
4/17/2013	EC	12d-dup	0.57	4.76	0.18	4.94	8.51	0.02	DG	23	GW
4/17/2013	EC	12s	1.01	5.55	0.08	5.64	7.36	<0.008	DG	23	GW
11/29/2012	EC	12s	0.15	5.18	0.18	5.36	9.86	<0.015	DG	23	GW
9/4/2012	EC	12s	0.04	6.17	0.51	6.69	8.92	<0.0015	DG	23	GW
11/29/2012	EC	12s-dup	0.45	5.22	0.21	5.43	9.61	<0.015	DG	23	GW
4/17/2013	EC	13	0.55	3.81	0.15	3.96	6.60	<0.008	DG	26	GW
11/29/2012	EC	13	0.21	5.67	0.19	5.86	8.61	0.01	DG	26	GW
9/4/2012	EC	13	0.15	6.29	2.40	8.68	8.52	0.01	DG	26	GW
4/17/2013	EC	Tank	59.64	0.02	56.55	56.58	79.24	7.69	Tank	-	Tank
11/29/2012	EC	Tank	69.33	<0.008	63.02	63.02	90.07	6.00	Tank	-	Tank
9/4/2012	EC	Tank	66.95	<0.008	76.45	76.45	75.04	4.29	Tank	-	Tank

Residential 100 (Site: Res-100)

Date	Site	Sample ID	NH_4-N (mg/L)	NO_3-N $+NO_2$ (mg/L)	DKN (mg/L)	TDN (mg/L)	Cl (mg/L)	PO_4-P (mg/L)	Location of piezometer	Distance From DF (m)	Sample Type
7/13/2012	Res-100	101	0.28	2.96	0.81	3.77	6.42	<DL	BG	-	GW
11/16/2012	Res-100	101	0.13	4.41	0.39	4.79	12.39	0.02	BG	-	GW
3/27/2013	Res-100	101	0.63	3.70	0.20	3.90	10.58	<0.008	BG	-	GW
7/13/2012	Res-100	101-rep	0.29	2.96	0.84	3.80	6.82	<DL	BG	-	GW
7/13/2012	Res-100	102	0.85	2.89	1.77	4.65	6.57	1.20	BG	-	GW
11/16/2012	Res-100	102	0.12	5.45	0.43	5.88	11.95	0.02	BG	-	GW

3/27/2013	Res-100	102	0.60	4.40	0.27	4.66	13.55	<0.008	BG	-	GW
7/13/2012	Res-100	103	2.08	<0.008	5.62	5.62	2.72	<DL	DF	-	GW
11/16/2012	Res-100	103	4.70	5.11	6.67	11.79	9.51	0.06	DF	-	GW
3/27/2013	Res-100	103	5.33	<0.008	5.81	5.81	12.96	0.09	DF	-	GW
7/13/2012	Res-100	103-rep	2.32	<0.008	5.66	5.66	3.16	<DL	DF	-	GW
7/13/2012	Res-100	104	0.22	<0.008	6.71	6.71	6.24	0.06	DF	-	GW
11/16/2012	Res-100	104	0.41	0.15	1.82	1.97	30.92	0.06	DF	-	GW
3/27/2013	Res-100	104	10.62	0.03	10.53	10.56	24.73	0.06	DF	-	GW
7/13/2012	Res-100	105	0.09	<0.008	1.67	1.67	2.05	0.09	DF	-	GW
3/27/2013	Res-100	105	0.88	0.36	1.15	1.51	14.79	0.10	DF	-	GW
7/13/2012	Res-100	110d	0.40	<0.008	3.01	3.01	3.72	1.14	DF	-	GW
11/16/2012	Res-100	110d	15.28	0.02	14.89	14.91	27.12	0.01	DF	-	GW
3/27/2013	Res-100	110d	2.36	<0.008	2.83	2.83	7.53	0.06	DF	-	GW
7/13/2012	Res-100	110s	26.66	<0.008	25.99	25.99	43.55	<DL	DF	-	GW
11/16/2012	Res-100	110s	19.12	0.03	19.04	19.08	35.10	<0.015	DF	-	GW
3/27/2013	Res-100	110s	14.63	<0.008	15.77	15.77	32.14	<0.008	DF	-	GW
7/13/2012	Res-100	107d	1.28	<0.008	3.91	3.91	2.99	0.87	DG	13	GW
11/16/2012	Res-100	107d	6.36	0.01	6.81	6.82	9.49	0.07	DG	13	GW
3/27/2013	Res-100	107d	3.30	<0.008	1.95	1.95	7.23	0.24	DG	13	GW
7/13/2012	Res-100	107s	5.69	0.01	10.51	10.52	5.07	0.07	DG	13	GW
11/16/2012	Res-100	107s	8.70	0.04	10.08	10.12	9.69	0.09	DG	13	GW
3/27/2013	Res-100	107s	7.08	<0.008	5.95	5.95	5.93	0.19	DG	13	GW
7/13/2012	Res-100	108d	5.14	4.45	7.11	11.56	44.94	<DL	DG	11	GW
11/16/2012	Res-100	108d	8.60	0.46	7.71	8.16	22.48	<0.015	DG	11	GW
3/27/2013	Res-100	108d	13.26	<0.008	13.29	13.29	24.91	<0.008	DG	11	GW
7/13/2012	Res-100	108m	11.51	2.11	11.56	13.67	11.98	0.14	DG	11	GW
11/16/2012	Res-100	108m	10.62	0.30	10.54	10.83	15.45	<0.015	DG	11	GW
3/27/2013	Res-100	108m	3.77	0.19	2.71	2.90	10.37	0.02	DG	11	GW

7/13/2012	Res-100	108s	0.57	1.15	3.20	4.35	38.90	0.15	DG	11	GW
3/27/2013	Res-100	108s	1.65	2.94	0.09	3.03	8.04	<0.008	DG	11	GW
7/13/2012	Res-100	109d	0.52	0.19	2.57	2.76	2.96	1.65	DG	10	GW
11/16/2012	Res-100	109d	7.37	0.02	7.64	7.66	13.08	0.25	DG	10	GW
3/27/2013	Res-100	109d	5.85	0.06	6.56	6.62	15.48	0.06	DG	10	GW
7/13/2012	Res-100	109s	5.86	0.09	5.71	5.80	13.77	<DL	DG	10	GW
11/16/2012	Res-100	109s	5.02	0.01	6.52	6.53	20.72	<0.015	DG	10	GW
3/27/2013	Res-100	109s	2.14	0.70	2.62	3.32	14.64	0.01	DG	10	GW
7/13/2012	Res-100	106	2.26	0.03	2.62	2.65	9.43	<DL	OSP	12	GW
11/16/2012	Res-100	106	3.24	0.02	3.54	3.56	11.56	0.06	OSP	12	GW
3/27/2013	Res-100	106	2.25	<0.008	0.65	0.65	12.65	<0.008	OSP	12	GW
11/16/2012	Res-100	106-dup	3.26	0.02	3.57	3.59	12.17	0.03	OSP	12	GW
11/16/2012	Res-100	pipe	3.31	3.23	3.46	6.69	15.22	0.27	DG	12	SW
3/27/2013	Res-100	pipe	0.63	3.30	0.30	3.60	11.87	0.00	DG	12	SW
7/13/2012	Res-100	stream	0.40	0.56	1.13	1.70	22.05	<DL	DG	14	SW
11/16/2012	Res-100	stream	1.04	0.58	1.28	1.86	21.97	0.01	DG	14	SW
3/27/2013	Res-100	stream	1.33	0.63	0.47	1.10	17.73	<0.008	DG	14	SW
7/13/2012	Res-100	Tank	35.02	<0.008	64.78	64.78	36.95	3.52	Tank	-	Tank
11/16/2012	Res-100	Tank	54.99	0.01	44.81	44.81	76.71	6.18	Tank	-	Tank
3/27/2013	Res-100	Tank	46.54	<0.008	38.38	38.38	74.85	7.61	Tank	-	Tank

Residential 200, 300, and 400

Date	Site	Sample ID	NH_4-N (mg/L)	NO_3+-N NO_2 (mg/L)	DKN (mg/L)	TDN (mg/L)	Cl (mg/L)	PO_4-P (mg/L)	Location of piezometer	Distance From DF (m)	Sample Type
9/19/2012	200	213	4.12	0.35	5.69	6.04	14.17	0.90	DG	14	GW
9/19/2012	200	207d	2.55	0.06	2.51	2.57	16.61	<0.0015	DG	24	GW
9/19/2012	200	207s	3.17	0.16	4.76	4.92	21.15	0.03	DG	24	GW
9/19/2012	200	209d	2.06	0.58	2.77	3.35	17.65	0.29	DG	24	GW
9/19/2012	200	211s	2.77	0.09	3.24	3.33	9.79	1.25	DG	25	GW
9/19/2012	200	212d	6.50	0.20	6.47	6.67	17.57	0.05	DG	24	GW
9/19/2012	200	212s	12.10	0.05	13.40	13.45	44.88	0.17	DG	24	GW
9/17/2012	300	300	0.21	0.15	0.79	0.93	1.22	0.65	BG	-	GW
9/17/2012	300	301	0.42	0.06	1.43	1.50	4.54	0.07	DF	-	GW
9/17/2012	300	302	1.31	0.02	1.95	1.97	10.01	0.55	DF	-	GW
9/17/2012	300	303	0.53	0.09	1.09	1.19	11.22	0.08	DF	-	GW
9/17/2012	300	305	0.25	0.06	1.06	1.12	6.14	0.11	DF	-	GW
9/17/2012	400	403	0.93	0.52	1.36	1.88	4.80	0.18	BG	-	GW
9/17/2012	400	401	1.66	0.24	3.80	4.04	10.39	0.92	DF	-	GW
9/17/2012	400	402	0.66	0.16	4.83	5.00	6.45	2.94	DF	-	GW

Appendix E: Environmental Readings (collected in the field) Water Quality Data. Water quality data was collected from the high school (HS), elementary school (ES), education center (EC), and Residential 100, 300, and 400 sites (Res-100, Res-300, Res-400). The data was collected from the background (BG), drainfield (DF) and downgradient (DG) areas at each site.

Table E1: Environmental Readings (collected using a TLC meter and YSI).

Environmental Readings					TLC Meter			YSI			
Site	Date	Sample Number	Location	Hydraulic Head (m)	DTW (m)	°C	µS/cm	°C	µS/cm	DO (mg/L)	pH
EC	9/4/2012	Tank	-	-	-	-	-	30.5	1336	2.0	6.8
EC	11/29/2012	Tank	-	-	-	-	-	12.5	1255	1.9	7.1
EC	1/30/2013	Tank	-	-	-	-	-	16.8	1066	2.2	7.4
EC	2/25/2013	Tank	-	-	-	-	-	9.6	828	1.7	7.2
EC	4/17/2013	Tank	-	-	-	-	-	20.8	1092	1.8	7.0
EC	3/23/2012	1d	BG	10.5	3.0	20.1	28	-	-	-	-
EC	4/1/2012	1d	BG	10.5	3.0	16.0	10	-	-	-	-
EC	6/7/2012	1d	BG	11.3	2.2	20.5	10	-	-	-	-
EC	6/19/2012	1d	BG	11.3	2.2	23.0	70	-	-	-	-
EC	6/24/2012	1d	BG	11.2	2.3	23.2	81	-	-	-	-
EC	7/5/2012	1d	BG	10.9	2.6	23.0	10	-	-	-	-
EC	8/15/2012	1d	BG	10.9	2.6	25.2	12	23.7	51	1.2	4.6
EC	9/4/2012	1d	BG	11.1	2.4	-	-	24.2	175	3.0	5.3
EC	11/29/2012	1d	BG	10.7	2.8	-	-	16.1	80	1.7	6.6
EC	1/30/2013	1d	BG	10.5	3.0	23.3	47	16.7	124	7.2	5.5
EC	2/13/2013	1d	BG	13.5	0.0	15.6	15	-	57	-	-
EC	2/25/2013	1d	BG	10.7	2.8	17.1	5	14.9	23	3.9	6.2
EC	4/17/2013	1d	BG	10.6	2.9	-	-	17.2	38	1.8	5.9

EC	12/11/2013	1d	BG	10.5	3.0	18.6	83	-	-	-	-
EC	8/15/2012	1s	BG	10.9	2.6	24.4	61	24.9	124	1.6	4.8
EC	9/4/2012	1s	BG	11.1	2.4	-	-	24.8	158	4.1	5.4
EC	11/29/2012	1s	BG	10.7	2.8	-	-	17.3	128	4.2	5.7
EC	1/30/2013	1s	BG	10.5	3.0	16.1	191	17.2	39	4.8	5.8
EC	2/13/2013	1s	BG	10.7	2.8	15.0	107	-	67	-	-
EC	2/25/2013	1s	BG	10.8	2.7	15.0	87	14.0	92	7.9	5.1
EC	4/17/2013	1s	BG	10.6	2.9	-	-	17.1	142	7.6	4.6
EC	12/11/2013	1s	BG	10.5	3.0	18.4	186	18.2	143	3.4	5.6
EC	3/23/2012	2d	DF	9.6	3.2	17.1	65	-	-	-	-
EC	4/1/2012	2d	DF	9.7	3.1	16.0	20	-	-	-	-
EC	6/7/2012	2d	DF	10.5	2.3	22.2	11	-	-	-	-
EC	6/19/2012	2d	DF	10.2	2.6	23.1	18	-	-	-	-
EC	6/24/2012	2d	DF	10.1	2.7	22.7	70	-	-	-	-
EC	7/5/2012	2d	DF	9.8	3.0	22.4	21	-	-	-	-
EC	8/15/2012	2d	DF	9.9	2.9	24.5	55	23.3	118	1.6	5.5
EC	9/4/2012	2d	DF	10.2	2.6	-	-	24.0	100	3.3	5.8
EC	11/29/2012	2d	DF	9.6	3.2	-	-	16.2	138	4.9	5.2
EC	1/30/2013	2d	DF	9.5	3.3	17.4	162	17.4	107	7.7	4.8
EC	2/13/2013	2d	DF	9.8	3.0	15.6	155	-	104	-	-
EC	2/25/2013	2d	DF	9.8	3.0	15.2	67	14.3	74	6.5	5.2
EC	4/17/2013	2d	DF	9.5	3.3	-	-	17.4	129	4.8	4.7
EC	12/11/2013	2d	DF	-	-	-	-	-	-	-	-
EC	8/15/2012	2s	DF	9.9	2.9	26.0	143	23.5	247	1.2	4.9
EC	9/4/2012	2s	DF	10.2	2.6	-	-	24.5	284	4.2	5.9
EC	11/29/2012	2s	DF	9.6	3.2	-	-	18.1	188	3.4	5.9
EC	1/30/2013	2s	DF	9.5	3.3	17.0	161	17.2	116	4.3	6.1
EC	2/13/2013	2s	DF	9.7	3.1	15.7	200	-	120	-	-

EC	2/25/2013	2s	DF	9.8	3.0	15.6	126	13.5	129	7.5	5.0
EC	4/17/2013	2s	DF	9.5	3.3	-	-	18.5	159	7.1	5.4
EC	12/11/2013	2s	DF	-	-	-	-	-	-	-	-
EC	3/23/2012	3	DF	9.1	4.0	16.7	64	-	-	-	-
EC	4/1/2012	3	DF	9.5	3.6	16.1	11	-	-	-	-
EC	6/7/2012	3	DF	9.0	4.1	18.2	8	-	-	-	-
EC	6/19/2012	3	DF	10.0	3.1	22.6	39	-	-	-	-
EC	6/24/2012	3	DF	9.9	3.2	21.9	57	-	-	-	-
EC	7/5/2012	3	DF	9.7	3.4	22.9	33	-	-	-	-
EC	8/15/2012	3	DF	9.7	3.4	23.9	18	23.8	101	1.9	7.0
EC	9/4/2012	3	DF	10.1	3.0	-	-	24.2	113	2.5	6.0
EC	11/29/2012	3	DF	9.5	3.6	-	-	16.2	152	1.4	6.2
EC	1/30/2013	3	DF	9.5	3.6	17.0	166	17.4	115	7.8	5.0
EC	2/13/2013	3	DF	9.7	3.4	15.6	169	-	111	-	-
EC	2/25/2013	3	DF	9.7	3.4	15.6	97	13.8	103	6.8	4.9
EC	4/17/2013	3	DF	9.5	3.6	-	-	17.6	130	7.0	5.2
EC	3/23/2012	4	DG ≤ 15m	9.2	3.7	17.7	51	-	-	-	-
EC	4/1/2012	4	DG ≤ 15m	7.4	5.5	16.4	20	-	-	-	-
EC	6/7/2012	4	DG ≤ 15m	8.1	4.8	18.0	13	-	-	-	-
EC	6/19/2012	4	DG ≤ 15m	9.7	3.2	21.9	61	-	-	-	-
EC	6/24/2012	4	DG ≤ 15m	9.6	3.3	20.6	74	-	-	-	-
EC	7/5/2012	4	DG ≤ 15m	9.4	3.5	23.0	20	-	-	-	-
EC	8/15/2012	4	DG ≤ 15m	9.4	3.5	22.6	15	22.4	73	0.9	6.1
EC	9/4/2012	4	DG ≤ 15m	9.7	3.2	-	-	23.0	120	2.0	6.0
EC	11/29/2012	4	DG ≤ 15m	9.3	3.6	-	-	17.7	135	1.5	6.2
EC	1/30/2013	4	DG ≤ 15m	9.2	3.7	-	172	17.5	114	7.4	4.8
EC	2/25/2013	4	DG ≤ 15m	9.4	3.5	14.2	96	13.4	108	6.1	4.8
EC	4/17/2013	4	DG ≤ 15m	9.2	3.7	-	-	18.1	103	2.0	5.5

EC	3/23/2012	5	DG ≤ 15m	9.3	3.5	16.4	45	-	-	-	-
EC	4/1/2012	5	DG ≤ 15m	9.4	3.4	15.6	83	-	-	-	-
EC	6/7/2012	5	DG ≤ 15m	10.1	2.7	18.0	35	-	-	-	-
EC	6/19/2012	5	DG ≤ 15m	9.8	3.0	19.5	90	-	-	-	-
EC	6/24/2012	5	DG ≤ 15m	9.6	3.2	19.9	80	-	-	-	-
EC	7/5/2012	5	DG ≤ 15m	9.4	3.4	25.9	35	-	-	-	-
EC	8/15/2012	5	DG ≤ 15m	9.6	3.2	23.4	90	22.0	164	1.3	5.3
EC	9/4/2012	5	DG ≤ 15m	9.9	2.9	-	-	23.0	159	4.9	5.4
EC	11/29/2012	5	DG ≤ 15m	9.4	3.4	-	-	18.0	145	5.1	5.4
EC	1/30/2013	5	DG ≤ 15m	9.4	3.4	-	192	17.3	129	8.6	4.5
EC	2/25/2013	5	DG ≤ 15m	9.6	3.2	14.9	113	14.1	115	6.4	4.6
EC	4/17/2013	5	DG ≤ 15m	9.3	3.5	-	-	18.0	143	6.0	5.1
EC	7/5/2012	10	DG ≥ 20m	-	2.3	20.2	102	-	-	-	-
EC	8/15/2012	10	DG ≥ 20m	-	2.2	22.0	61	21.5	122	1.9	4.2
EC	9/4/2012	10	DG ≥ 20m	-	1.3	-	-	22.4	138	3.9	4.9
EC	11/29/2012	10	DG ≥ 20m	-	2.4	-	-	14.5	124	2.1	4.8
EC	1/30/2013	10	DG ≥ 20m	-	2.4	-	-	15.0	96	6.6	4.7
EC	2/25/2013	10	DG ≥ 20m	-	2.3	11.6	78	11.7	85	3.9	4.7
EC	4/17/2013	10	DG ≥ 20m	-	2.4	-	-	15.1	116	2.7	4.8
EC	12/11/2013	10	DG ≥ 20m	-	2.5	16.2	150	16.2	99	3.1	4.7
EC	7/5/2012	11d	DG ≥ 20m	-	1.2	21.4	110	-	-	-	-
EC	8/15/2012	11d	DG ≥ 20m	-	1.0	22.9	67	21.9	118	1.3	4.4
EC	9/4/2012	11d	DG ≥ 20m	-	0.6	-	-	22.3	138	3.5	5.2
EC	11/29/2012	11d	DG ≥ 20m	-	1.0	-	-	15.2	138	3.1	4.7
EC	1/30/2013	11d	DG ≥ 20m	-	1.0	-	-	14.1	111	7.7	4.5
EC	2/25/2013	11d	DG ≥ 20m	-	0.9	13.1	94	12.1	100	4.4	4.4
EC	4/17/2013	11d	DG ≥ 20m	-	1.2	-	-	15.2	131	3.2	4.9
EC	12/11/2013	11d	DG ≥ 20m	-	1.0	16.0	90	16.1	122	2.9	4.6

EC	7/5/2012	11s	DG ≥ 20m	-	1.1	21.1	12	-	-	-	-
EC	8/15/2012	11s	DG ≥ 20m	-	0.9	23.4	67	22.0	122	2.6	4.4
EC	9/4/2012	11s	DG ≥ 20m	-	0.6	-	-	22.0	140	4.5	4.9
EC	11/29/2012	11s	DG ≥ 20m	-	0.9	-	-	14.6	132	4.0	4.8
EC	1/30/2013	11s	DG ≥ 20m	-	1.0	-	-	14.1	105	8.3	4.6
EC	2/25/2013	11s	DG ≥ 20m	-	0.8	12.1	91	11.5	97	5.4	4.4
EC	4/17/2013	11s	DG ≥ 20m	-	1.0	-	-	15.4	128	4.0	4.7
EC	12/11/2013	11s	DG ≥ 20m	-	0.9	15.9	161	15.9	110	3.0	4.5
EC	7/5/2012	12d	DG ≥ 20m	-	2.8	18.2	73	-	-	-	-
EC	8/15/2012	12d	DG ≥ 20m	-	2.7	21.2	37	19.8	131	1.6	4.7
EC	9/4/2012	12d	DG ≥ 20m	-	1.9	-	-	22.3	171	3.7	4.7
EC	11/29/2012	12d	DG ≥ 20m	-	2.7	-	-	14.6	149	2.6	5.6
EC	1/30/2013	12d	DG ≥ 20m	-	2.5	-	-	15.5	117	4.6	4.7
EC	2/25/2013	12d	DG ≥ 20m	-	2.2	14.1	53	13.4	106	4.6	4.6
EC	4/17/2013	12d	DG ≥ 20m	-	2.2	-	-	16.7	141	2.3	5.1
EC	12/11/2013	12d	DG ≥ 20m	-	1.6	16.0	155	16.2	100	3.5	4.6
EC	7/5/2012	12s	DG ≥ 20m	-	1.8	20.5	30	-	-	-	-
EC	8/15/2012	12s	DG ≥ 20m	-	1.6	23.2	50	21.2	111	2.5	4.5
EC	9/4/2012	12s	DG ≥ 20m	-	1.2	-	-	22.8	138	4.0	4.7
EC	11/29/2012	12s	DG ≥ 20m	-	1.5	-	-	14.6	126	3.4	5.0
EC	1/30/2013	12s	DG ≥ 20m	-	1.6	-	-	14.1	104	9.7	4.5
EC	2/25/2013	12s	DG ≥ 20m	-	1.3	12.2	47	12.0	95	5.9	4.4
EC	4/17/2013	12s	DG ≥ 20m	-	2.5	-	-	15.6	126	4.3	5.0
EC	12/11/2013	12s	DG ≥ 20m	-	2.8	17.4	182	16.9	119	3.3	5.1
EC	7/5/2012	13	DG ≥ 20m	-	1.7	20.5	73	-	-	-	-
EC	8/15/2012	13	DG ≥ 20m	-	1.6	23.5	42	22.5	134	1.7	4.8
EC	9/4/2012	13	DG ≥ 20m	-	1.2	-	-	21.9	140	3.2	4.9
EC	11/29/2012	13	DG ≥ 20m	-	1.6	-	-	14.5	137	4.1	4.9

EC	1/30/2013	13	DG ≥ 20m	-	1.6	-	-	14.1	108	7.2	4.6
EC	2/25/2013	13	DG ≥ 20m	-	1.4	12.4	45	12.1	99	5.0	4.6
EC	4/17/2013	13	DG ≥ 20m	-	1.7	-	-	15.4	123	4.1	4.9
EC	12/11/2013	13	DG ≥ 20m	-	1.7	16.0	167	15.9	105	4.7	4.6
EC	3/23/2012	6	DG ≥ 30m	4.8	2.0	16.5	58	-	-	-	-
EC	4/1/2012	6	DG ≥ 30m	5.1	1.7	16.9	93	-	-	-	-
EC	6/8/2012	6	DG ≥ 30m	5.0	1.8	20.6	75	-	-	-	-
EC	6/19/2012	6	DG ≥ 30m	4.9	1.9	20.6	87	-	-	-	-
EC	6/24/2012	6	DG ≥ 30m	4.9	1.9	21.6	72	-	-	-	-
EC	7/5/2012	6	DG ≥ 30m	4.8	2.0	22.5	26	-	-	-	-
EC	8/15/2012	6	DG ≥ 30m	4.8	2.0	22.4	58	21.7	129	1.3	5.0
EC	9/4/2012	6	DG ≥ 30m	4.8	2.0	-	-	22.4	87	1.2	5.4
EC	11/29/2012	6	DG ≥ 30m	5.0	1.8	-	-	16.1	178	3.8	5.0
EC	1/30/2013	6	DG ≥ 30m	5.0	1.8	-	-	15.4	160	9.1	4.4
EC	2/25/2013	6	DG ≥ 30m	4.9	1.9	13.0	109	12.6	131	5.7	4.5
EC	4/17/2013	6	DG ≥ 30m	4.9	1.9	-	-	16.9	170	4.7	4.4
EC	12/11/2013	6	DG ≥ 30m	4.9	1.9	17.1	120	17.3	154	4.6	5.1
EC	4/1/2012	7	DG ≥ 30m	4.9	1.8	16.5	102	-	-	-	-
EC	6/8/2012	7	DG ≥ 30m	4.8	1.9	20.2	91	-	-	-	-
EC	6/19/2012	7	DG ≥ 30m	4.7	2.0	20.6	76	-	-	-	-
EC	6/24/2012	7	DG ≥ 30m	4.7	2.0	20.6	68	-	-	-	-
EC	7/5/2012	7	DG ≥ 30m	4.6	2.1	22.4	25	-	-	-	-
EC	8/15/2012	7	DG ≥ 30m	4.7	2.0	23.4	59	22.2	108	1.2	4.8
EC	9/4/2012	7	DG ≥ 30m	5.5	1.2	-	-	22.8	130	2.6	4.7
EC	11/29/2012	7	DG ≥ 30m	4.8	1.9	-	-	16.1	186	1.2	5.6
EC	1/30/2013	7	DG ≥ 30m	4.8	1.9	-	-	15.4	134	4.6	5.3
EC	2/25/2013	7	DG ≥ 30m	4.8	1.9	13.6	107	12.6	116	5.7	4.9
EC	4/17/2013	7	DG ≥ 30m	4.7	2.0	-	-	17.0	138	2.0	5.1

EC	12/11/2013	7	DG ≥ 30m	4.8	1.9	17.0	112	17.0	148	1.4	5.6
EC	4/1/2012	8	DG ≥ 30m	4.7	1.9	16.1	101	-	-	-	-
EC	6/8/2012	8	DG ≥ 30m	4.7	1.9	18.9	106	-	-	-	-
EC	6/19/2012	8	DG ≥ 30m	4.6	2.0	19.6	99	-	-	-	-
EC	6/24/2012	8	DG ≥ 30m	4.5	2.1	19.2	105	-	-	-	-
EC	7/5/2012	8	DG ≥ 30m	4.5	2.1	20.6	42	-	-	-	-
EC	8/15/2012	8	DG ≥ 30m	4.6	2.0	22.5	58	21.3	161	1.3	4.2
EC	9/4/2012	8	DG ≥ 30m	5.1	1.5	-	-	22.3	184	2.8	4.8
EC	11/29/2012	8	DG ≥ 30m	4.6	2.0	-	-	16.7	160	2.1	4.5
EC	1/30/2013	8	DG ≥ 30m	4.6	2.0	-	-	16.1	126	8.8	4.4
EC	2/25/2013	8	DG ≥ 30m	4.8	1.8	13.6	129	12.1	110	5.5	4.2
EC	4/17/2013	8	DG ≥ 30m	4.6	2.0	-	-	18.3	85	3.2	4.7
EC	12/11/2013	8	DG ≥ 30m	4.6	2.0	17.0	182	17.2	130	2.2	4.4
EC	3/23/2012	9	DG ≥ 30m	4.8	1.5	17.7	25	-	-	-	-
EC	4/1/2012	9	DG ≥ 30m	5.3	1.0	16.6	57	-	-	-	-
EC	6/8/2012	9	DG ≥ 30m	5.0	1.3	20.4	1	-	-	-	-
EC	6/19/2012	9	DG ≥ 30m	4.8	1.5	20.6	19	-	-	-	-
EC	6/24/2012	9	DG ≥ 30m	4.8	1.5	21.0	27	-	-	-	-
EC	7/5/2012	9	DG ≥ 30m	4.7	1.6	21.7	25	-	-	-	-
EC	8/15/2012	9	DG ≥ 30m	4.7	1.6	24.4	35	23.0	78	1.5	4.3
EC	9/4/2012	9	DG ≥ 30m	4.7	1.6	-	-	22.1	60	2.5	5.2
EC	11/29/2012	9	DG ≥ 30m	4.9	1.4	-	-	15.4	76	4.6	4.9
EC	1/30/2013	9	DG ≥ 30m	4.9	1.4	-	-	15.9	66	8.3	4.5
EC	2/25/2013	9	DG ≥ 30m	5.1	1.2	12.4	42	12.0	55	6.4	4.7
EC	4/17/2013	9	DG ≥ 30m	5.0	1.3	-	-	16.8	86	3.0	4.6
EC	12/11/2013	9	DG ≥ 30m	4.9	1.4	16.5	85	16.7	66	4.3	4.4
ES	9/10/2012	Tank/D-Box	-	-	-	-	-	26.9	901	2.1	6.9

ES	11/14/2012	Tank/D-Box	-	-	-	-	-	15.2	491	0.8	7.5
ES	1/9/2013	Tank/D-Box	-	-	-	-	-	17.1	1367	1.1	7.6
ES	2/27/2013	Tank/D-Box	-	-	-	-	-	14.6	1005	2.1	7.2
ES	3/25/2013	Tank/D-Box	-	-	-	-	-	15.1	1387	2.5	6.8
ES	6/22/2012	1	BG	8.4	3.8	22.4	15	-	-	-	-
ES	8/27/2012	1	BG	8.5	3.6	24.7	89	23.3	167	1.7	5.9
ES	9/10/2012	1	BG	-	-	-	-	-	-	-	-
ES	11/14/2012	1	BG	8.5	3.7	-	-	18.2	57	7.5	6.7
ES	12/15/2012	1	BG	8.3	3.8	20.4	240	-	-	-	-
ES	1/9/2013	1	BG	8.5	3.7	-	-	18.1	150	2.9	6.5
ES	2/27/2013	1	BG	11.3	0.9	11.2	23	11.6	32	7.0	6.5
ES	3/25/2013	1	BG	-	-	-	-	-	-	-	-
ES	6/22/2012	2	BG	7.9	4.2	21.6	46	-	-	-	-
ES	7/27/2012	2	BG	8.1	4.0	24.5	44	24.1	110	-	-
ES	8/27/2012	2	BG	8.0	4.1	22.9	63	23.4	148	4.2	5.6
ES	9/10/2012	2	BG	8.4	3.7	-	-	22.8	97	4.6	5.0
ES	11/14/2012	2	BG	8.0	4.1	-	-	18.5	104	10.6	5.2
ES	12/15/2012	2	BG	7.7	4.4	20.4	136	-	-	-	-
ES	1/9/2013	2	BG	7.9	4.2	-	-	18.4	111	6.0	5.0
ES	2/27/2013	2	BG	8.0	4.1	17.5	74	14.2	83	6.7	5.3
ES	3/25/2013	2	BG	8.0	4.1	-	-	15.7	123	7.9	6.5
ES	6/22/2012	3	BG	7.8	4.3	21.7	55	-	-	-	-
ES	7/27/2012	3	BG	8.1	4.0	25.2	67	24.5	158	2.3	-
ES	8/27/2012	3	BG	7.8	4.3	23.4	32	23.2	103	3.2	5.5

ES	9/10/2012	3	BG	8.4	3.7	-	-	22.9	139	2.9	5.5
ES	11/14/2012	3	BG	7.3	4.8	-	-	17.8	31	9.5	6.0
ES	1/9/2013	3	BG	7.9	4.2	-	-	18.4	92	5.1	4.6
ES	2/27/2013	3	BG	8.0	4.1	17.5	85	14.1	92	5.8	4.7
ES	3/25/2013	3	BG	8.0	4.1	-	-	15.8	119	4.5	4.8
ES	6/23/2012	9	BG	6.2	5.6	19.1	1	-	-	-	-
ES	8/27/2012	9	BG	6.5	5.3	20.6	4	23.6	79	7.7	6.5
ES	9/10/2012	9	BG	7.0	4.8	-	-	23.9	64	5.6	7.1
ES	11/14/2012	9	BG	6.5	5.3	-	-	19.0	41	13.1	6.0
ES	12/15/2012	9	BG	6.3	5.5	20.4	58	-	-	-	-
ES	1/9/2013	9	BG	6.5	5.3	-	-	20.8	59	8.4	7.3
ES	2/27/2013	9	BG	6.5	5.3	18.7	-	15.0	52	7.0	7.0
ES	3/25/2013	9	BG	6.5	5.3	-	-	14.4	41	8.7	6.7
ES	6/22/2012	4	DF	7.9	4.2	20.6	336	-	-	-	-
ES	7/27/2012	4	DF	8.1	4.0	24.4	70	23.3	318	6.2	-
ES	8/27/2012	4	DF	7.9	4.2	22.5	161	22.4	425	2.3	6.3
ES	9/10/2012	4	DF	8.5	3.6	-	-	22.8	465	6.4	6.3
ES	11/14/2012	4	DF	8.0	4.1	-	-	18.4	361	8.4	6.3
ES	1/9/2013	4	DF	8.0	4.1	-	-	18.8	607	5.2	6.0
ES	2/27/2013	4	DF	8.1	4.0	17.1	394	14.8	529	6.7	5.5
ES	3/25/2013	4	DF	8.0	4.1	-	-	15.4	745	5.9	5.7
ES	6/22/2012	5	DF	7.6	4.2	20.0	369	-	-	-	-
ES	8/27/2012	5	DF	7.6	4.2	22.6	349	23.2	652	3.4	5.1
ES	9/10/2012	5	DF	8.1	3.7	-	-	22.2	615	5.5	5.6
ES	11/14/2012	5	DF	7.7	4.1	-	-	19.9	506	9.0	6.1
ES	1/9/2013	5	DF	7.7	4.1	-	-	18.6	580	5.2	6.2
ES	2/27/2013	5	DF	7.7	4.1	16.6	102	14.3	127	7.5	6.4
ES	3/25/2013	5	DF	7.8	4.0	-	-	15.1	658	5.2	6.0

ES	6/22/2012	6	DF	7.0	5.0	20.1	507	-	-	-	-
ES	7/27/2012	6	DF	7.2	4.8	22.9	433	22.9	767	4.7	-
ES	8/27/2012	6	DF	7.0	5.0	22.7	441	22.6	733	3.4	5.4
ES	9/10/2012	6	DF	7.5	4.5	-	-	22.2	698	5.8	6.1
ES	11/14/2012	6	DF	7.1	4.9	-	-	19.5	498	4.3	6.0
ES	1/9/2013	6	DF	7.2	4.8	-	-	19.6	857	3.7	5.9
ES	2/27/2013	6	DF	7.2	4.8	17.5	700	14.8	606	4.2	5.9
ES	3/25/2013	6	DF	7.2	4.8	-	-	15.0	773	4.0	6.1
ES	6/22/2012	7	DF	5.9	6.1	19.7	682	-	-	-	-
ES	8/27/2012	7	DF	5.8	6.2	20.6	625	21.5	1187	3.8	5.8
ES	9/10/2012	7	DF	6.0	6.0	-	-	22.2	1036	7.8	6.4
ES	11/14/2012	7	DF	5.9	6.1	-	-	19.6	988	8.7	7.1
ES	1/9/2013	7	DF	5.9	6.1	-	-	19.9	1218	2.4	7.0
ES	2/27/2013	7	DF	5.8	6.2	18.5	992	15.8	883	3.7	6.9
ES	3/25/2013	7	DF	5.9	6.1	-	-	15.9	1112	1.9	6.9
ES	6/22/2012	10	DF	7.8	4.2	20.6	280	-	-	-	-
ES	7/27/2012	10	DF	8.0	4.0	22.9	125	23.2	281	5.0	-
ES	8/27/2012	10	DF	7.9	4.1	22.5	203	22.9	399	5.1	6.4
ES	9/10/2012	10	DF	8.4	3.6	-	-	23.3	597	7.5	6.6
ES	11/14/2012	10	DF	7.9	4.1	-	-	18.6	567	7.7	6.5
ES	12/15/2012	10	DF	7.8	4.2	19.2	1215	-	-	-	-
ES	1/9/2013	10	DF	8.0	4.0	-	-	19.0	970	7.1	6.4
ES	2/27/2013	10	DF	8.0	4.0	17.1	821	14.7	688	7.2	6.2
ES	3/25/2013	10	DF	8.0	4.0	-	-	14.9	867	7.5	6.4
ES	7/27/2012	11d	DF	5.2	6.8	21.5	-	-	-	-	-
ES	8/27/2012	11d	DF	5.1	6.9	19.4	231	20.2	404	6.9	6.9
ES	9/10/2012	11d	DF	5.2	6.8	-	-	25.0	471	4.6	7.2
ES	11/14/2012	11d	DF	5.0	7.0	-	-	18.3	306	6.8	7.5

ES	1/9/2013	11d	DF	5.1	6.9	-	-	20.2	356	3.8	7.7
ES	2/27/2013	11d	DF	5.0	7.0	19.4	260	15.9	286	4.6	7.4
ES	3/25/2013	11d	DF	5.1	6.9	-	-	16.6	370	2.1	6.7
ES	6/22/2012	11s	DF	5.0	7.0	20.1	229	-	-	-	-
ES	7/27/2012	11s	DF	5.1	6.9	21.0	-	-	-	-	-
ES	8/27/2012	11s	DF	5.1	6.9	20.6	258	20.0	432	6.9	6.9
ES	9/10/2012	11s	DF	5.3	6.7	-	-	23.3	431	5.3	7.3
ES	11/14/2012	11s	DF	5.1	7.0	-	-	18.5	337	15.8	7.5
ES	1/9/2013	11s	DF	5.1	6.9	-	-	20.0	384	3.0	7.6
ES	2/27/2013	11s	DF	5.1	7.0	19.1	289	14.6	311	4.3	7.3
ES	3/25/2013	11s	DF	5.1	6.9	-	-	16.4	371	2.3	7.1
ES	6/22/2012	13d	DF	7.4	4.6	20.4	373	-	-	-	-
ES	7/27/2012	13d	DF	7.5	4.6	22.5	423	-	423	-	-
ES	8/27/2012	13d	DF	7.4	4.6	22.5	353	23.0	708	6.6	1.6
ES	9/10/2012	13d	DF	7.5	4.5	-	-	22.9	683	5.4	5.5
ES	11/14/2012	13d	DF	7.4	4.6	-	-	18.4	518	9.4	6.5
ES	1/9/2013	13d	DF	7.1	4.9	-	-	20.1	546	6.8	6.5
ES	2/27/2013	13d	DF	7.2	4.8	18.1	414	14.7	392	6.8	5.6
ES	3/25/2013	13d	DF	7.2	4.8	-	-	15.0	487	6.8	6.2
ES	7/27/2012	13s	DF	7.3	4.7	22.0	365	22.9	365	6.9	-
ES	8/27/2012	13s	DF	7.1	4.9	21.1	353	-	-	-	-
ES	9/10/2012	13s	DF	7.7	4.3	-	-	24.3	727	6.7	6.4
ES	11/14/2012	13s	DF	7.2	4.9	-	-	18.4	465	8.8	5.5
ES	1/9/2013	13s	DF	7.4	4.7	-	-	-	-	-	-
ES	2/27/2013	13s	DF	7.4	4.6	17.6	489	14.9	433	7.3	6.1
ES	3/25/2013	13s	DF	7.5	4.5	-	-	16.0	618	6.8	6.3
ES	6/22/2012	14	DF	5.7	6.2	20.5	492	-	-	-	-
ES	8/27/2012	14	DF	5.6	6.3	20.5	531	20.5	1010	5.1	3.6

ES	9/10/2012	14	DF	5.9	6.0	-	-	21.2	838	6.5	6.7
ES	11/14/2012	14	DF	5.7	6.2	-	-	17.5	796	8.5	7.0
ES	12/15/2012	14	DF	8.1	3.8	20.1	1462	-	-	-	-
ES	1/9/2013	14	DF	5.8	6.1	-	-	20.3	1038	5.1	7.2
ES	2/27/2013	14	DF	5.7	6.1	19.1	892	16.4	717	6.9	7.2
ES	3/25/2013	14	DF	5.8	6.1	-	-	15.2	997	5.5	6.5
ES	1/9/2013	Spring 3	DG	-	-	-	-	17.6	294	6.8	7.3
ES	7/27/2012	12d	DG ≤ 15m	5.1	7.1	20.6	236	-	236	-	-
ES	8/27/2012	12d	DG ≤ 15m	5.0	7.1	19.5	237	20.0	502	2.3	7.2
ES	9/10/2012	12d	DG ≤ 15m	2.1	10.0	-	-	22.2	540	5.1	7.4
ES	11/14/2012	12d	DG ≤ 15m	5.0	7.1	-	-	17.9	418	3.1	7.4
ES	1/9/2013	12d	DG ≤ 15m	5.0	7.1	-	-	19.7	506	3.0	7.6
ES	2/27/2013	12d	DG ≤ 15m	5.0	7.1	19.4	382	15.8	402	4.4	7.3
ES	3/25/2013	12d	DG ≤ 15m	5.0	7.1	-	-	16.1	503	1.4	7.1
ES	6/22/2012	12s	DG ≤ 15m	5.0	7.1	19.5	297	-	-	-	-
ES	7/27/2012	12s	DG ≤ 15m	5.0	7.1	21.6	303	-	303	-	-
ES	8/27/2012	12s	DG ≤ 15m	5.1	7.1	19.4	287	20.7	590	2.1	7.4
ES	9/10/2012	12s	DG ≤ 15m	5.2	6.9	-	-	22.3	550	5.7	7.2
ES	11/14/2012	12s	DG ≤ 15m	5.0	7.1	-	-	19.4	254	-	-
ES	6/22/2012	15	DG ≥ 20m	4.8	7.2	20.0	74	-	-	-	-
ES	7/27/2012	15	DG ≥ 20m	5.0	7.0	21.5	131	-	131	-	-
ES	8/27/2012	15	DG ≥ 20m	4.9	7.1	20.3	43	20.4	143	1.6	7.5
ES	9/10/2012	15	DG ≥ 20m	5.0	7.0	-	-	22.1	282	4.3	7.6
ES	11/14/2012	15	DG ≥ 20m	4.8	7.2	-	-	18.3	239	3.5	7.5
ES	1/9/2013	15	DG ≥ 20m	4.9	7.2	-	-	19.7	193	5.6	8.1
ES	2/27/2013	15	DG ≥ 20m	4.9	7.1	18.5	197	15.4	245	3.7	7.3
ES	3/25/2013	15	DG ≥ 20m	4.9	7.2	-	-	16.9	307	2.1	7.6
ES	6/22/2012	16	DG ≥ 30m	4.4	1.0	21.2	11	-	-	-	-

ES	7/27/2012	16	DG ≥ 30m	4.6	0.8	23.9	179	-	369	3.3	-
ES	8/27/2012	16	DG ≥ 30m	4.5	0.9	23.6	173	21.7	356	3.2	7.3
ES	9/10/2012	16	DG ≥ 30m	4.6	0.8	-	-	21.8	388	2.2	6.9
ES	11/14/2012	16	DG ≥ 30m	4.5	0.9	-	-	15.8	286	2.9	7.1
ES	1/9/2013	16	DG ≥ 30m	4.6	0.9	-	-	15.0	366	3.4	7.0
ES	2/27/2013	16	DG ≥ 30m	4.7	0.8	13.2	279	12.5	249	3.5	6.7
ES	3/25/2013	16	DG ≥ 30m	4.6	0.8	-	-	12.5	351	3.7	7.5
ES	6/23/2012	17	DG ≥ 30m	4.3	1.0	20.5	170	-	-	-	-
ES	7/27/2012	17	DG ≥ 30m	4.5	0.8	22.9	273	-	630	3.1	-
ES	8/27/2012	17	DG ≥ 30m	4.4	0.9	23.1	311	22.0	639	1.7	7.1
ES	9/10/2012	17	DG ≥ 30m	4.4	0.8	-	-	22.0	604	3.3	6.7
ES	11/14/2012	17	DG ≥ 30m	4.4	0.9	-	-	15.4	394	3.2	6.7
ES	1/9/2013	17	DG ≥ 30m	4.5	0.8	-	-	13.3	431	2.5	6.8
ES	2/27/2013	17	DG ≥ 30m	4.6	0.7	11.7	313	11.3	282	6.5	6.7
ES	3/25/2013	17	DG ≥ 30m	4.4	0.9	-	-	11.3	355	2.4	7.1
ES	6/23/2012	18	DG ≥ 30m	4.5	1.3	21.4	385	-	-	-	-
ES	7/27/2012	18	DG ≥ 30m	4.6	1.2	23.9	205	-	691	4.8	-
ES	8/27/2012	18	DG ≥ 30m	4.5	1.3	23.6	299	22.4	715	3.6	7.5
ES	9/10/2012	18	DG ≥ 30m	4.6	1.2	-	-	20.5	727	2.7	6.9
ES	11/14/2012	18	DG ≥ 30m	4.5	1.3	-	-	15.4	561	7.8	7.2
ES	12/15/2012	18	DG ≥ 30m	4.5	1.3	15.6	938	-	-	-	-
ES	1/9/2013	18	DG ≥ 30m	4.6	1.2	-	-	14.3	695	5.4	7.0
ES	2/27/2013	18	DG ≥ 30m	4.6	1.2	12.7	463	11.5	466	4.2	6.6
ES	3/25/2013	18	DG ≥ 30m	4.6	1.2	-	-	12.0	653	5.6	7.0
ES	6/23/2012	Spring 1	DG ≥ 30m	-	-	18.0	296	-	-	-	-
ES	7/27/2012	Spring 1	DG ≥ 30m	-	-	-	-	-	449	-	-
ES	8/27/2012	Spring 1	DG ≥ 30m	-	-	18.9	279	19.5	466	5.2	2.1
ES	9/10/2012	Spring 1	DG ≥ 30m	-	-	-	-	19.4	504	6.5	6.9

ES	11/14/2012	Spring 1	DG ≥ 30m	-	-	-	-	18.5	425	7.9	6.9
ES	12/15/2012	Spring 1	DG ≥ 30m	-	-	19.4	672	-	-	-	-
ES	1/9/2013	Spring 1	DG ≥ 30m	-	-	-	-	18.7	476	4.7	7.1
ES	2/27/2013	Spring 1	DG ≥ 30m	-	-	-	-	16.6	361	4.5	6.9
ES	3/25/2013	Spring 1	DG ≥ 30m	-	-	-	-	16.1	478	4.7	7.0
ES	6/23/2012	Spring 2	DG ≥ 40m	-	-	18.9	255	-	-	-	-
ES	7/27/2012	Spring 2	DG ≥ 40m	-	-	-	-	-	442	-	-
ES	8/27/2012	Spring 2	DG ≥ 40m	-	-	-	-	-	-	-	-
ES	9/10/2012	Spring 2	DG ≥ 40m	-	-	-	-	20.0	507	8.6	7.2
ES	11/14/2012	Spring 2	DG ≥ 40m	-	-	-	-	-	-	-	-
ES	1/9/2013	Spring 2	DG ≥ 40m	-	-	-	-	-	-	-	-
ES	2/27/2013	Spring 2	DG ≥ 40m	-	-	-	-	14.5	79	7.6	7.1
ES	3/25/2013	Spring 2	DG ≥ 40m	-	-	-	-	-	-	-	-
ES	6/23/2012	Spring/Stream	DG ≥ 40m	-	-	19.5	298	-	-	-	-
ES	7/27/2012	Spring/Stream	DG ≥ 40m	-	-	-	-	-	125	11.0	-
ES	8/27/2012	Spring/Stream	DG ≥ 40m	-	-	-	-	-	-	-	-
ES	9/10/2012	Spring/Stream	DG ≥ 40m	-	-	-	-	20.1	504	6.8	7.1
ES	11/14/2012	Spring/Stream	DG ≥ 40m	-	-	-	-	13.5	123	14.5	7.2
ES	1/9/2013	Spring/Stream	DG ≥ 40m	-	-	-	-	17.4	460	7.6	7.1
ES	2/27/2013	Spring/Stream	DG ≥ 40m	-	-	-	-	12.0	325	7.2	7.1
ES	3/25/2013	Spring/Stream	DG ≥ 40m	-	-	-	-	15.3	452	8.2	7.1
ES	6/23/2012	19	DG ≥ 50m	-	1.9	18.9	191	-	-	-	-
ES	7/27/2012	19	DG ≥ 50m	-	1.6	-	-	-	352	3.0	-
ES	11/14/2012	19	DG ≥ 50m	-	1.8	-	-	14.9	267	5.0	6.8
ES	1/9/2013	19	DG ≥ 50m	-	1.7	-	-	12.6	297	1.4	6.8
ES	2/27/2013	19	DG ≥ 50m	-	1.4	10.0	131	9.6	156	9.6	7.1
ES	3/25/2013	19	DG ≥ 50m	-	1.9	-	-	10.5	316	1.5	6.8
ES	6/23/2012	20	DG ≥ 50m	-	1.0	20.0	171	-	-	-	-

ES	7/27/2012	20	DG ≥ 50m	-	0.9	-	444	-	-	-	-
ES	9/10/2012	20	DG ≥ 50m	-	0.9	-	-	21.1	462	1.3	6.8
ES	11/14/2012	20	DG ≥ 50m	-	0.9	-	-	14.2	351	3.1	7.1
ES	1/9/2013	20	DG ≥ 50m	-	0.9	-	-	11.7	427	3.4	7.0
ES	2/27/2013	20	DG ≥ 50m	-	0.9	10.1	188	10.2	198	7.1	7.0
ES	3/25/2013	20	DG ≥ 50m	-	1.0	-	-	10.6	404	2.1	7.1
ES	6/23/2012	5m Downstream	DG ≥ 50m	-	-	21.5	186	-	-	-	-
ES	7/27/2012	5m Downstream	DG ≥ 50m	-	-	-	-	-	129	12.0	-
ES	8/27/2012	5m Downstream	DG ≥ 50m	-	-	-	-	-	-	-	-
ES	9/10/2012	5m Downstream	DG ≥ 50m	-	-	-	-	20.2	184	7.8	7.5
ES	11/14/2012	5m Downstream	DG ≥ 50m	-	-	-	-	13.5	134	15.3	7.2
ES	1/9/2013	5m Downstream	DG ≥ 50m	-	-	-	-	12.8	176	13.6	7.4
ES	2/27/2013	5m Downstream	DG ≥ 50m	-	-	-	-	11.3	91	10.4	7.5
ES	3/25/2013	5m Downstream	DG ≥ 50m	-	-	-	-	11.0	170	10.5	7.4
ES	6/23/2012	5m Upstream	DG ≥ 50m	-	-	20.7	86	-	-	-	-
ES	7/27/2012	5m Upstream	DG ≥ 50m	-	-	-	-	-	-	-	-
ES	8/27/2012	5m Upstream	DG ≥ 50m	-	-	-	-	-	-	-	-
ES	9/10/2012	5m Upstream	DG ≥ 50m	-	-	-	-	20.1	136	7.7	7.4
ES	11/14/2012	5m Upstream	DG ≥ 50m	-	-	-	-	13.9	130	15.1	7.2
ES	1/9/2013	5m Upstream	DG ≥ 50m	-	-	-	-	12.6	158	10.7	7.3
ES	2/27/2013	5m Upstream	DG ≥ 50m	-	-	-	-	11.6	329	8.8	7.1
ES	3/25/2013	5m Upstream	DG ≥ 50m	-	-	-	-	10.7	161	10.2	7.3

ES	3/25/2013	Other Stream Bank	DG ≥ 50m	-	-	-	-	14.8	275	7.1	7.1
ES	6/23/2012	21	DG ≥ 70m	-	1.4	22.9	98	-	-	-	-
ES	7/27/2012	21	DG ≥ 70m	-	-	-	-	-	-	-	-
ES	8/27/2012	21	DG ≥ 70m	-	-	-	-	-	-	-	-
ES	9/10/2012	21	DG ≥ 70m	-	-	-	-	-	-	-	-
ES	11/14/2012	21	DG ≥ 70m	-	1.4	-	-	15.5	312	6.4	7.0
ES	2/27/2013	21	DG ≥ 70m	-	1.2	11.9	279	10.1	252	5.2	7.1
ES	6/22/2012	8	OSP	5.4	6.1	19.7	535	-	-	-	-
ES	7/27/2012	8	OSP	5.5	6.0	21.5	442	-	442	-	-
ES	8/27/2012	8	OSP	5.5	6.1	20.0	455	20.6	898	5.7	6.2
ES	9/10/2012	8	OSP	5.7	5.8	-	-	21.5	924	5.5	7.1
ES	11/14/2012	8	OSP	5.4	6.2	-	-	17.4	746	7.7	7.3
ES	1/9/2013	8	OSP	5.5	6.1	-	-	19.9	932	5.1	7.4
ES	2/27/2013	8	OSP	5.4	6.1	18.6	706	15.5	823	6.5	6.4
ES	3/25/2013	8	OSP	5.5	6.1	-	-	15.6	884	6.6	7.3
Res-100	7/13/2012	Tank	-	-	-	-	-	27.4	1003	1.7	6.1
Res-100	9/10/2012	Tank	-	-	-	-	-	24.9	894	0.8	7.2
Res-100	11/16/2012	Tank	-	-	-	-	-	18.3	707	0.3	6.6
Res-100	1/25/2013	Tank	-	-	-	-	-	-	557	1.4	6.6
Res-100	3/27/2013	Tank	-	-	-	-	-	13.8	799	0.4	6.3
Res-100	5/30/2013	Tank	-	-	-	-	-	25.6	1185	-	-
Res-100	7/13/2012	101	BG	12.9	0.8	-	-	25.1	212	3.4	8.4
Res-100	9/10/2012	101	BG	12.7	1.0	-	-	22.6	180	1.4	3.4
Res-100	11/16/2012	101	BG	13.0	0.7	-	-	17.4	174	2.1	4.8
Res-100	1/25/2013	101	BG	12.8	0.9	-	-	13.0	-	4.5	4.5
Res-100	3/27/2013	101	BG	12.8	0.9	-	-	12.8	228	3.4	5.7
Res-100	5/30/2013	101	BG	12.7	1.0	-	-	21.5	103	-	-
Res-100	7/13/2012	102	BG	13.0	0.7	-	-	25.0	171	3.2	8.3

Res-100	9/10/2012	102	BG	12.8	0.9	-	-	24.1	132	1.3	3.3
Res-100	11/16/2012	102	BG	13.1	0.6	-	-	17.7	316	3.0	5.1
Res-100	1/25/2013	102	BG	13.0	0.7	-	-	-	-	3.0	4.8
Res-100	3/27/2013	102	BG	13.0	0.7	-	-	13.1	184	2.9	5.3
Res-100	5/30/2013	102	BG	12.9	0.8	-	-	23.1	107	-	-
Res-100	7/13/2012	103	DF	12.9	0.3	-	-	25.9	248	3.9	7.6
Res-100	9/10/2012	103	DF	12.3	0.9	-	-	24.3	203	0.9	2.9
Res-100	11/16/2012	103	DF	12.9	0.3	-	-	16.2	201	1.0	6.2
Res-100	1/25/2013	103	DF	12.8	0.4	-	-	-	164	1.9	6.0
Res-100	3/27/2013	103	DF	12.7	0.5	-	-	11.9	186	1.5	5.8
Res-100	5/30/2013	103	DF	12.7	0.5	-	-	22.1	76	-	-
Res-100	7/13/2012	104	DF	12.9	0.0	-	-	27.2	226	1.8	7.3
Res-100	9/10/2012	104	DF	12.4	0.5	-	-	24.4	396	0.6	2.6
Res-100	11/16/2012	104	DF	12.9	0.0	-	-	13.6	138	4.6	6.5
Res-100	1/25/2013	104	DF	12.9	0.0	-	-	-	206	2.9	6.3
Res-100	3/27/2013	104	DF	12.5	0.4	-	-	11.6	279	1.7	6.4
Res-100	5/30/2013	104	DF	12.4	0.5	-	-	23.0	439	-	-
Res-100	7/13/2012	105	DF	12.8	0.2	-	-	26.4	313	2.6	7.7
Res-100	9/10/2012	105	DF	12.4	0.6	-	-	24.1	556	2.1	3.1
Res-100	1/25/2013	105	DF	12.5	0.5	-	-	11.6	181	2.4	6.5
Res-100	3/27/2013	105	DF	12.5	0.5	-	-	11.4	239	1.6	6.3
Res-100	5/30/2013	105	DF	12.4	0.6	-	-	22.2	99	-	-
Res-100	7/13/2012	110d	DF	12.5	0.4	-	-	26.6	69	2.0	7.9
Res-100	9/10/2012	110d	DF	12.3	0.6	-	-	24.4	345	-	-
Res-100	11/16/2012	110d	DF	12.4	0.5	-	-	16.4	372	0.9	6.3
Res-100	1/25/2013	110d	DF	12.4	0.5	-	-	11.4	219	2.6	6.3
Res-100	3/27/2013	110d	DF	12.3	0.6	-	-	10.9	117	1.5	6.1
Res-100	5/30/2013	110d	DF	12.3	0.6	-	-	22.5	25	-	-

Res-100	7/13/2012	110s	DF	12.5	0.4	-	-	26.1	600	2.4	7.5
Res-100	9/10/2012	110s	DF	12.3	0.6	-	-	24.4	649	1.1	2.1
Res-100	11/16/2012	110s	DF	12.6	0.3	-	-	15.8	484	1.2	6.4
Res-100	1/25/2013	110s	DF	12.4	0.5	-	-	10.4	333	2.7	6.3
Res-100	3/27/2013	110s	DF	12.4	0.5	-	-	11.1	551	1.7	5.9
Res-100	5/30/2013	110s	DF	12.3	0.6	-	-	21.6	212	-	-
Res-100	7/13/2012	106	DG ≤ 15m	11.7	0.6	-	-	22.1	85	1.9	7.5
Res-100	9/10/2012	106	DG ≤ 15m	11.5	0.8	-	-	-	158	0.6	1.6
Res-100	11/16/2012	106	DG ≤ 15m	11.7	0.6	-	-	16.7	79	2.2	6.1
Res-100	1/25/2013	106	DG ≤ 15m	11.5	0.8	-	-	12.0	49	2.9	5.6
Res-100	3/27/2013	106	DG ≤ 15m	11.5	0.8	-	-	12.3	60	1.6	5.5
Res-100	5/30/2013	106	DG ≤ 15m	11.5	0.8	-	-	20.4	63	-	-
Res-100	7/13/2012	107d	DG ≤ 15m	11.5	1.0	-	-	21.4	131	2.2	5.6
Res-100	9/10/2012	107d	DG ≤ 15m	11.4	1.1	-	-	22.1	64	1.3	2.3
Res-100	11/16/2012	107d	DG ≤ 15m	11.5	1.0	-	-	17.3	112	1.1	6.3
Res-100	1/25/2013	107d	DG ≤ 15m	11.3	1.2	-	-	13.0	54	2.5	5.8
Res-100	3/27/2013	107d	DG ≤ 15m	11.3	1.2	-	-	12.3	68	1.8	5.8
Res-100	5/30/2013	107d	DG ≤ 15m	11.3	1.2	-	-	19.1	43	-	-
Res-100	7/13/2012	107s	DG ≤ 15m	11.5	1.0	-	-	23.3	156	1.9	5.9
Res-100	9/10/2012	107s	DG ≤ 15m	11.4	1.1	-	-	22.4	231	1.0	2.0
Res-100	11/16/2012	107s	DG ≤ 15m	11.5	1.0	-	-	16.3	142	0.8	5.9
Res-100	1/25/2013	107s	DG ≤ 15m	11.3	1.2	-	-	13.0	83	1.7	5.6
Res-100	3/27/2013	107s	DG ≤ 15m	11.3	1.2	-	-	11.4	112	3.2	5.7
Res-100	5/30/2013	107s	DG ≤ 15m	11.4	1.1	-	-	19.0	63	-	-
Res-100	7/13/2012	108d	DG ≤ 15m	11.3	1.1	-	-	21.8	434	1.4	5.8
Res-100	9/10/2012	108d	DG ≤ 15m	11.1	1.3	-	-	21.9	352	1.0	2.0
Res-100	11/16/2012	108d	DG ≤ 15m	11.1	1.3	-	-	16.0	222	1.7	6.0
Res-100	1/25/2013	108d	DG ≤ 15m	11.1	1.3	-	-	12.1	144	2.1	5.6

Res-100	3/27/2013	108d	DG ≤ 15m	11.1	1.3	-	-	12.2	413	1.2	5.9
Res-100	5/30/2013	108d	DG ≤ 15m	11.1	1.3	-	-	17.4	289	-	-
Res-100	7/13/2012	108m	DG ≤ 15m	11.3	1.1	-	-	21.6	328	1.4	5.9
Res-100	9/10/2012	108m	DG ≤ 15m	11.0	1.4	-	-	21.6	317	1.4	2.4
Res-100	11/16/2012	108m	DG ≤ 15m	11.1	1.3	-	-	15.9	265	1.7	6.6
Res-100	1/25/2013	108m	DG ≤ 15m	11.0	1.4	-	-	13.0	146	4.8	6.3
Res-100	3/27/2013	108m	DG ≤ 15m	11.1	1.3	-	-	11.7	187	2.5	6.3
Res-100	5/30/2013	108m	DG ≤ 15m	11.0	1.4	-	-	18.0	99	-	-
Res-100	7/13/2012	108s	DG ≤ 15m	11.4	1.0	-	-	22.9	326	1.9	6.1
Res-100	9/10/2012	108s	DG ≤ 15m	-	-	-	-	dry	dry	dry	dry
Res-100	1/25/2013	108s	DG ≤ 15m	-	-	-	-	dry	dry	dry	dry
Res-100	3/27/2013	108s	DG ≤ 15m	-	-	-	-	dry	dry	dry	dry
Res-100	5/30/2013	108s	DG ≤ 15m	-	-	-	-	dry	dry	dry	dry
Res-100	7/13/2012	109d	DG ≤ 15m	11.4	1.0	-	-	21.2	100	1.6	6.6
Res-100	9/10/2012	109d	DG ≤ 15m	11.3	1.1	-	-	21.2	205	0.7	1.7
Res-100	11/16/2012	109d	DG ≤ 15m	11.5	0.9	-	-	15.5	218	0.9	6.4
Res-100	1/25/2013	109d	DG ≤ 15m	11.4	1.0	-	-	12.0	202	3.1	6.1
Res-100	3/27/2013	109d	DG ≤ 15m	11.4	1.0	-	-	11.9	254	1.0	6.2
Res-100	5/30/2013	109d	DG ≤ 15m	11.3	1.1	-	-	18.6	25	-	-
Res-100	7/13/2012	109s	DG ≤ 15m	11.4	1.0	-	-	21.9	307	2.0	6.1
Res-100	9/10/2012	109s	DG ≤ 15m	11.3	1.1	-	-	21.4	267	0.5	1.5
Res-100	11/16/2012	109s	DG ≤ 15m	11.4	1.0	-	-	15.3	295	1.0	6.1
Res-100	1/25/2013	109s	DG ≤ 15m	11.3	1.1	-	-	10.6	163	2.3	6.0
Res-100	3/27/2013	109s	DG ≤ 15m	11.3	1.1	-	-	11.5	199	1.8	5.9
Res-100	5/30/2013	109s	DG ≤ 15m	11.2	1.2	-	-	19.2	67	-	-
Res-100	3/27/2013	Pipe	DG ≤ 15m	-	-	-	-	12.1	196	6.5	5.7
Res-100	5/30/2013	Pipe	DG ≤ 15m	-	-	-	-	-	-	-	-
Res-100	7/13/2012	Stream	DG ≤ 15m	-	-	-	-	26.0	210	4.3	6.5

Res-100	11/16/2012	Stream	DG ≤ 15m	-	-	-	-	12.5	151	7.1	6.6
Res-100	1/25/2013	Stream	DG ≤ 15m	-	-	-	-	-	148	5.9	5.9
Res-100	3/27/2013	Stream	DG ≤ 15m	-	-	-	-	7.8	169	11.6	6.3
Res-100	5/30/2013	Stream	DG ≤ 15m	-	-	-	-	-	-	-	-
Res-200	9/17/2012	206	DG ≤ 15m	11.7	0.3	-	-	-	-	-	-
Res-200	9/17/2012	207d	DG ≤ 15m	11.5	0.5	-	-	21.7	100	2.0	5.1
Res-200	9/17/2012	207s	DG ≤ 15m	11.2	0.7	-	-	22.0	355	2.4	5.8
Res-200	9/17/2012	208s	DG ≤ 15m	11.6	0.2	-	-	-	-	-	-
Res-200	9/17/2012	209d	DG ≤ 15m	11.4	0.5	-	-	22.9	205	1.9	5.5
Res-200	9/17/2012	209s	DG ≤ 15m	11.3	0.5	-	-	-	-	-	-
Res-200	9/17/2012	210s	DG ≤ 15m	11.5	0.1	-	-	-	-	-	-
Res-200	9/17/2012	211	DG ≤ 15m	11.5	0.4	-	-	22.0	162	2.5	-
Res-200	9/17/2012	212d	DG ≤ 15m	11.6	0.5	-	-	21.6	162	2.1	5.4
Res-200	9/17/2012	212s	DG ≤ 15m	11.1	0.9	-	-	21.9	574	2.9	6.4
Res-200	9/17/2012	213	DG ≤ 15m	11.6	0.6	-	-	22.0	200	2.1	6.1
Res-300	9/17/2012	300	BG	13.0	0.8	-	-	24.1	65	1.9	5.6
Res-300	9/17/2012	301	DF	12.7	0.9	-	-	24.0	76	1.9	5.8
Res-300	9/17/2012	302	DF	12.7	0.9	-	-	23.8	101	1.1	5.8
Res-300	9/17/2012	303	DF	12.4	1.1	-	-	25.1	112	1.6	5.8
Res-300	9/17/2012	305	DF	12.2	1.0	-	-	24.0	96	1.7	5.5
Res-400	9/17/2012	403	BG	15.2	1.7	-	-	23.1	169	1.5	4.6
Res-400	9/17/2012	401	DF	15.0	1.7	-	-	25.2	116	1.8	5.6
Res-400	9/17/2012	402	DF	15.0	1.5	-	-	25.3	126	1.6	5.6
HS	9/7/2012	Tank	-	-	-	-	-	28.0	1760	1.0	7.2
HS	11/14/2012	Tank	-	-	-	-	-	17.4	1303	1.0	7.3
HS	1/14/2013	Tank	-	-	-	-	-	16.3	599	1.4	6.6
HS	2/28/2013	Tank	-	-	-	-	-	12.3	1033	1.7	7.6
HS	4/10/2013	Tank	-	-	-	-	-	18.2	1212	1.4	6.9

HS	6/22/2012	1d	BG	6.6	1.3	21.6	38	-	-	-	-
HS	7/24/2012	1d	BG	7.1	0.8	27.0	73	23.8	126	1.2	5.0
HS	8/24/2012	1d	BG	7.3	0.6	26.0	6	24.6	77	3.5	5.6
HS	9/7/2012	1d	BG	7.0	0.9	-	-	25.3	107	2.8	5.2
HS	11/14/2012	1d	BG	-	-	-	-	-	-	-	-
HS	12/21/2012	1d	BG	6.8	1.1	16.1	260	-	-	-	-
HS	1/14/2013	1d	BG	6.9	1.0	-	-	16.1	216	2.8	4.8
HS	2/28/2013	1d	BG	7.0	0.9	13.2	218	12.6	472	4.6	4.2
HS	4/10/2013	1d	BG	6.9	1.0	-	-	14.6	82	4.1	5.1
HS	6/22/2012	1s	BG	6.6	1.3	22.4	26	-	-	-	-
HS	7/24/2012	1s	BG	7.2	0.7	26.5	50	25.0	103	1.3	4.9
HS	8/24/2012	1s	BG	7.3	0.6	25.7	6	23.2	49	3.4	5.3
HS	9/7/2012	1s	BG	7.1	0.8	-	-	25.4	126	2.4	5.2
HS	11/14/2012	1s	BG	6.7	1.2	-	-	17.1	147	1.7	5.0
HS	1/14/2013	1s	BG	6.9	1.0	-	-	15.3	105	5.1	5.4
HS	2/28/2013	1s	BG	7.1	0.8	12.9	18	11.5	183	5.1	4.7
HS	4/10/2013	1s	BG	6.9	1.0	-	-	15.9	295	3.6	4.6
HS	6/22/2012	2	BG	6.4	1.3	21.6	1	-	-	-	-
HS	7/24/2012	2	BG	6.9	0.8	23.0	50	25.0	35	2.1	5.5
HS	8/24/2012	2	BG	6.5	1.3	25.2	6	23.2	76	3.4	5.0
HS	9/7/2012	2	BG	7.0	0.7	-	-	24.7	80	2.2	5.2
HS	11/14/2012	2	BG	6.7	1.0	-	-	17.1	97	2.3	5.5
HS	1/14/2013	2	BG	6.9	0.9	-	-	16.4	131	1.8	5.3
HS	2/28/2013	2	BG	7.0	0.7	13.4	73	11.7	82	5.9	4.4
HS	4/10/2013	2	BG	6.7	1.0	-	-	16.3	161	2.3	5.1
HS	6/22/2012	3	BG	6.9	1.2	21.6	10	-	-	-	-
HS	7/24/2012	3	BG	7.0	1.0	24.6	-	25.6	29	1.3	5.6
HS	8/24/2012	3	BG	6.3	1.7	25.4	5	23.1	25	2.7	5.3

HS	9/7/2012	3	BG	7.0	1.1	-	-	25.0	34	2.5	5.5
HS	11/14/2012	3	BG	6.7	1.4	-	-	16.8	33	2.3	5.7
HS	1/14/2013	3	BG	7.1	1.0	-	-	15.2	36	4.0	5.6
HS	2/28/2013	3	BG	7.1	1.0	13.1	23	11.4	28	6.4	4.6
HS	4/10/2013	3	BG	6.7	1.4	-	-	15.8	28	2.9	5.5
HS	6/22/2012	4	BG	6.6	1.2	21.0	4	-	-	-	-
HS	7/24/2012	4	BG	7.1	0.8	22.5	36	24.6	18	1.3	4.6
HS	8/24/2012	4	BG	7.2	0.7	25.2	-	22.7	19	3.1	5.0
HS	9/7/2012	4	BG	7.0	0.8	-	-	24.6	31	3.6	5.6
HS	11/14/2012	4	BG	6.7	1.1	-	-	16.5	40	2.2	5.7
HS	1/14/2013	4	BG	6.6	1.2	-	-	15.6	29	4.4	5.6
HS	2/28/2013	4	BG	7.0	0.8	12.9	13	11.8	31	6.8	4.4
HS	4/10/2013	4	BG	6.7	1.2	-	-	15.5	34	3.5	5.2
HS	6/22/2012	5d	BG	6.6	1.4	21.1	12	-	-	-	-
HS	7/24/2012	5d	BG	7.1	0.9	26.0	11	24.6	50	1.3	5.8
HS	8/24/2012	5d	BG	7.3	0.7	25.1	11	21.5	54	2.9	4.9
HS	9/7/2012	5d	BG	7.0	1.0	-	-	24.4	54	2.0	5.1
HS	11/14/2012	5d	BG	-	-	-	-	-	-	-	-
HS	1/14/2013	5d	BG	6.8	1.2	-	-	15.8	40	4.7	5.5
HS	2/28/2013	5d	BG	6.9	1.1	12.9	1	11.7	44	6.9	4.7
HS	4/10/2013	5d	BG	-	-	-	-	-	-	-	-
HS	6/22/2012	5s	BG	6.6	1.4	21.5	8	-	-	-	-
HS	7/24/2012	5s	BG	6.9	1.1	25.7	1	23.9	42	1.3	6.2
HS	8/24/2012	5s	BG	7.0	1.0	25.4	7	21.7	46	2.7	5.5
HS	9/7/2012	5s	BG	7.0	1.0	-	-	24.4	48	3.4	5.4
HS	11/14/2012	5s	BG	6.7	1.3	-	-	16.7	37	5.8	6.1
HS	1/14/2013	5s	BG	-	-	-	-	-	-	-	-
HS	2/28/2013	5s	BG	-	-	-	-	-	-	-	-

HS	4/10/2013	5s	BG	6.6	1.3	-	-	16.3	49	6.6	6.1
HS	6/22/2012	6	BG	6.6	1.4	20.0	20	-	-	-	-
HS	7/24/2012	6	BG	6.9	1.2	23.6	8	23.2	60	1.3	5.5
HS	8/24/2012	6	BG	7.3	0.7	24.5	20	22.1	65	2.4	5.2
HS	9/7/2012	6	BG	7.0	1.0	-	-	23.9	64	2.8	5.4
HS	11/14/2012	6	BG	6.7	1.3	-	-	16.9	53	4.2	5.4
HS	1/14/2013	6	BG	6.9	1.2	-	-	15.0	64	5.1	6.2
HS	2/28/2013	6	BG	7.0	1.0	12.9	44	11.9	65	5.3	5.1
HS	4/10/2013	6	BG	6.7	1.3	-	-	15.6	59	3.2	5.1
HS	6/22/2012	7	BG	6.6	1.6	21.7	4	-	-	-	-
HS	6/23/2012	7	BG	6.6	1.6	22.2	8	-	-	-	-
HS	7/24/2012	7	BG	6.9	1.3	25.0	1	24.2	40	1.9	4.7
HS	8/24/2012	7	BG	7.2	1.0	24.9	17	23.8	62	1.9	5.4
HS	9/7/2012	7	BG	7.0	1.2	-	-	24.2	57	2.7	5.9
HS	11/14/2012	7	BG	6.7	1.5	-	-	16.4	79	5.2	7.3
HS	12/21/2012	7	BG	6.7	1.5	13.6	15	-	-	-	-
HS	1/14/2013	7	BG	6.8	1.3	-	-	14.2	24	6.7	8.3
HS	2/28/2013	7	BG	7.0	1.2	12.6	4	11.5	100	7.8	5.0
HS	4/10/2013	7	BG	6.7	1.5	-	-	15.8	33	7.1	7.6
HS	6/22/2012	14	BG	6.7	1.5	23.4	14	-	-	-	-
HS	7/24/2012	14	BG	7.1	1.1	25.5	70	26.5	18	1.3	4.6
HS	8/24/2012	14	BG	7.2	1.0	26.9	-	23.0	27	2.2	6.5
HS	9/7/2012	14	BG	7.0	1.2	-	-	26.0	32	2.7	5.9
HS	11/14/2012	14	BG	6.8	1.4	-	-	17.3	30	3.6	5.9
HS	1/14/2013	14	BG	6.9	1.3	-	-	15.4	32	6.5	6.0
HS	2/28/2013	14	BG	7.0	1.2	13.6	10	12.7	117	8.7	5.4
HS	4/10/2013	14	BG	6.7	1.4	-	-	15.4	24	5.7	5.5
HS	6/22/2012	8	DF	6.6	2.0	21.7	61	-	-	-	-

HS	7/24/2012	8	DF	7.0	1.6	25.5	47	24.4	183	1.6	6.3
HS	8/24/2012	8	DF	7.2	1.4	26.0	12	23.6	69	2.1	5.7
HS	9/7/2012	8	DF	7.0	1.7	-	-	24.7	87	3.7	5.8
HS	11/14/2012	8	DF	7.0	1.6	-	-	18.6	213	5.1	5.4
HS	1/14/2013	8	DF	6.9	1.7	-	-	15.0	335	9.1	5.3
HS	2/28/2013	8	DF	7.0	1.6	13.2	73	12.1	97	9.1	5.2
HS	4/10/2013	8	DF	6.7	1.9	-	-	16.0	111	9.7	7.7
HS	6/22/2012	9	DF	6.6	2.1	21.7	11	-	-	-	-
HS	7/24/2012	9	DF	7.1	1.5	24.9	12	24.1	49	1.5	5.7
HS	8/24/2012	9	DF	7.2	1.4	25.9	14	23.8	64	2.1	5.2
HS	9/7/2012	9	DF	7.0	1.6	-	-	24.3	76	4.0	5.8
HS	11/14/2012	9	DF	7.1	1.6	-	-	17.4	62	4.2	6.2
HS	1/14/2013	9	DF	6.9	1.7	-	-	15.5	68	8.3	6.0
HS	2/28/2013	9	DF	7.0	1.7	13.0	37	11.7	69	8.4	5.6
HS	4/10/2013	9	DF	6.7	1.9	-	-	15.3	79	8.1	6.5
HS	6/22/2012	11	DF	6.6	2.0	21.5	5	-	-	-	-
HS	6/23/2012	11	DF	6.6	2.0	22.9	9	-	-	-	-
HS	7/24/2012	11	DF	7.1	1.6	26.1	3	25.2	42	1.9	5.9
HS	8/24/2012	11	DF	7.2	1.4	25.9	-	23.3	37	1.4	6.3
HS	9/7/2012	11	DF	7.0	1.6	-	-	24.6	39	3.1	5.6
HS	11/14/2012	11	DF	6.7	2.0	-	-	17.2	39	6.4	6.2
HS	1/14/2013	11	DF	6.9	1.8	-	-	16.0	38	7.4	6.8
HS	2/28/2013	11	DF	7.0	1.6	13.9	7	12.8	54	7.4	6.6
HS	4/10/2013	11	DF	6.7	2.0	-	-	15.5	40	6.9	6.7
HS	6/22/2012	12	DF	5.9	2.0	22.5	154	-	-	-	-
HS	7/24/2012	12	DF	6.3	1.6	26.1	151	25.4	293	2.0	6.4
HS	8/24/2012	12	DF	6.5	1.4	26.1	126	24.5	284	2.2	7.0
HS	9/7/2012	12	DF	6.2	1.7	-	-	25.0	336	2.8	6.6

HS	11/14/2012	12	DF	6.3	1.6	-	-	18.6	234	5.1	7.0
HS	1/14/2013	12	DF	6.2	1.7	-	-	16.2	460	6.5	5.9
HS	2/28/2013	12	DF	6.3	1.6	14.0	276	12.9	460	8.3	6.2
HS	4/10/2013	12	DF	5.9	2.0	-	-	15.6	497	6.8	7.2
HS	6/22/2012	13d	DF	6.6	2.0	22.9	446	-	-	-	-
HS	7/24/2012	13d	DF	7.1	1.5	26.1	659	25.3	1095	2.6	6.0
HS	8/24/2012	13d	DF	7.3	1.3	26.4	633	23.5	1075	1.9	6.4
HS	9/7/2012	13d	DF	7.0	1.6	-	-	24.7	802	3.2	6.3
HS	11/14/2012	13d	DF	7.0	1.6	-	-	17.5	726	4.1	6.6
HS	12/21/2012	13d	DF	6.8	1.8	17.1	1776	-	-	-	-
HS	1/14/2013	13d	DF	6.9	1.7	-	-	16.7	1278	3.4	6.2
HS	2/28/2013	13d	DF	7.1	1.5	14.0	851	13.4	819	5.8	6.1
HS	4/10/2013	13d	DF	6.7	1.9	-	-	15.8	1000	7.1	6.7
HS	6/22/2012	13s	DF	6.6	2.0	21.9	635	-	-	-	-
HS	6/23/2012	13s	DF	6.6	2.0	23.6	625	-	-	-	-
HS	7/24/2012	13s	DF	7.0	1.6	26.0	351	24.9	838	3.7	6.7
HS	8/24/2012	13s	DF	7.3	1.3	26.4	123	23.8	362	2.9	6.6
HS	9/7/2012	13s	DF	7.0	1.6	-	-	24.9	363	3.1	6.2
HS	11/14/2012	13s	DF	7.1	1.5	-	-	17.9	453	1.9	6.6
HS	12/21/2012	13s	DF	6.8	1.8	17.7	1027	-	-	-	-
HS	1/14/2013	13s	DF	6.9	1.7	-	-	16.3	1002	6.6	6.1
HS	2/28/2013	13s	DF	7.1	1.5	13.9	470	12.7	479	8.0	6.4
HS	4/10/2013	13s	DF	6.7	1.9	-	-	15.5	763	6.2	6.8
HS	6/22/2012	15	DF	6.6	1.8	22.9	81	-	-	-	-
HS	7/24/2012	15	DF	7.0	1.4	26.4	79	25.1	174	3.1	6.5
HS	8/24/2012	15	DF	7.2	1.2	26.2	66	23.5	158	1.8	4.9
HS	9/7/2012	15	DF	7.0	1.4	-	-	25.0	181	1.8	6.5
HS	11/14/2012	15	DF	6.7	1.7	-	-	18.5	260	5.8	7.1

HS	1/14/2013	15	DF	6.9	1.5	-	-	15.9	404	7.1	6.8
HS	2/28/2013	15	DF	7.0	1.4	13.9	369	13.1	396	7.6	6.4
HS	4/10/2013	15	DF	6.7	1.7	-	-	15.5	703	6.7	6.9
HS	6/22/2012	16	DF	6.6	1.9	22.1	16	-	-	-	-
HS	7/24/2012	16	DF	7.1	1.4	25.9	14	25.0	70	2.3	6.5
HS	8/24/2012	16	DF	6.7	1.8	25.2	1	23.5	32	2.4	6.5
HS	9/7/2012	16	DF	7.0	1.5	-	-	24.9	38	3.9	5.8
HS	11/14/2012	16	DF	6.7	1.7	-	-	18.9	129	3.2	6.8
HS	1/14/2013	16	DF	6.9	1.6	-	-	15.8	275	8.2	6.7
HS	2/28/2013	16	DF	7.1	1.4	13.6	100	12.8	224	8.2	5.4
HS	4/10/2013	16	DF	6.7	1.7	-	-	15.5	533	6.6	6.7
HS	6/22/2012	17	DF	6.6	1.8	21.9	181	-	-	-	-
HS	6/23/2012	17	DF	6.6	1.8	22.7	200	-	-	-	-
HS	7/24/2012	17	DF	7.1	1.4	26.1	216	24.9	508	1.3	5.2
HS	8/24/2012	17	DF	7.2	1.2	26.0	103	23.7	303	2.3	-
HS	9/7/2012	17	DF	7.0	1.4	-	-	25.0	330	2.7	6.4
HS	11/14/2012	17	DF	6.7	1.7	-	-	17.6	903	1.9	6.5
HS	1/14/2013	17	DF	6.9	1.5	-	-	15.7	841	8.7	6.8
HS	2/28/2013	17	DF	7.0	1.4	13.6	860	12.5	791	8.8	5.8
HS	4/10/2013	17	DF	6.7	1.7	-	-	15.9	1190	7.7	6.5
HS	6/22/2012	18	DF	6.6	1.7	22.6	116	-	-	-	-
HS	7/24/2012	18	DF	7.1	1.2	26.9	58	25.5	162	1.6	4.6
HS	9/7/2012	18	DF	7.0	1.4	-	-	26.0	184	2.0	6.3
HS	11/14/2012	18	DF	6.7	1.6	-	-	18.7	390	4.6	6.2
HS	1/14/2013	18	DF	6.9	1.4	-	-	15.6	316	5.0	6.1
HS	2/28/2013	18	DF	7.0	1.3	13.2	257	12.6	320	6.1	6.2
HS	4/10/2013	18	DF	6.7	1.6	-	-	15.5	515	5.2	6.4
HS	6/22/2012	24d	DF	6.6	1.8	19.7	22	-	-	-	-

HS	7/24/2012	24d	DF	7.0	1.4	29.6	186	26.1	224	1.4	4.2
HS	8/24/2012	24d	DF	7.2	1.2	26.5	139	24.1	143	0.8	7.0
HS	9/7/2012	24d	DF	6.9	1.4	-	-	26.0	527	2.5	6.6
HS	11/14/2012	24d	DF	6.7	1.7	-	-	18.1	437	3.7	6.8
HS	1/14/2013	24d	DF	6.8	1.5	-	-	16.5	255	6.0	6.8
HS	2/28/2013	24d	DF	7.0	1.4	13.9	494	12.6	478	5.1	6.5
HS	4/10/2013	24d	DF	6.7	1.7	-	-	15.7	650	6.8	6.6
HS	7/24/2012	24s	DF	7.0	1.3	26.1	94	24.8	270	2.9	3.9
HS	8/24/2012	24s	DF	7.2	1.2	26.4	83	24.2	188	3.3	6.7
HS	9/7/2012	24s	DF	7.0	1.4	-	-	25.6	240	4.5	6.4
HS	11/14/2012	24s	DF	6.7	1.7	-	-	18.1	323	4.0	6.8
HS	1/14/2013	24s	DF	6.9	1.5	-	-	15.7	242	7.4	6.5
HS	2/28/2013	24s	DF	7.0	1.4	13.5	163	12.8	190	7.4	6.3
HS	4/10/2013	24s	DF	6.7	1.6	-	-	15.2	526	6.5	6.8
HS	6/22/2012	20	DG	6.7	1.6	22.9	13	-	-	-	-
HS	7/24/2012	20	DG	7.0	1.2	22.5	6	26.6	54	1.3	6.5
HS	8/24/2012	20	DG	7.2	1.0	26.6	1	22.6	47	2.3	6.1
HS	9/7/2012	20	DG	7.0	1.2	-	-	25.8	64	4.6	6.0
HS	11/14/2012	20	DG	6.7	1.5	-	-	18.1	46	5.6	6.5
HS	1/14/2013	20	DG	6.9	1.3	-	-	15.7	41	7.5	6.2
HS	2/28/2013	20	DG	7.0	1.2	13.2	19	11.9	33	6.5	6.0
HS	4/10/2013	20	DG	6.7	1.5	-	-	15.9	44	7.5	6.1
HS	9/7/2012	19	DG OSP	7.1	1.1	-	-	25.6	63	3.0	6.4
HS	11/14/2012	19	DG OSP	6.7	1.5	-	-	17.7	47	6.1	6.6
HS	1/14/2013	19	DG OSP	6.9	1.3	-	-	16.1	50	8.8	7.3
HS	2/28/2013	19	DG OSP	7.1	1.1	13.0	23	11.9	38	7.1	6.6
HS	4/10/2013	19	DG OSP	6.7	1.4	-	-	15.7	46	7.0	6.5
HS	7/24/2012	25d	DG ≤ 15m	-	1.2	27.9	124	25.9	110	1.2	6.5

HS	8/24/2012	25d	DG ≤ 15m	-	1.0	26.4	85	24.0	203	1.2	6.9
HS	9/7/2012	25d	DG ≤ 15m	-	1.2	-	-	24.0	499	2.1	6.5
HS	11/14/2012	25d	DG ≤ 15m	-	1.5	-	-	17.8	558	1.3	6.8
HS	1/14/2013	25d	DG ≤ 15m	-	1.4	-	-	17.2	1016	3.7	6.3
HS	2/28/2013	25d	DG ≤ 15m	-	1.2	13.7	555	13.3	565	4.7	6.4
HS	4/10/2013	25d	DG ≤ 15m	-	1.5	-	-	16.2	578	5.0	6.4
HS	7/24/2012	25m	DG ≤ 15m	-	1.1	25.1	45	25.5	69	1.7	5.1
HS	8/24/2012	25m	DG ≤ 15m	-	1.0	26.0	49	23.8	112	1.2	6.9
HS	9/7/2012	25m	DG ≤ 15m	-	1.2	-	-	25.0	115	3.2	6.4
HS	11/14/2012	25m	DG ≤ 15m	-	1.5	-	-	18.3	128	2.6	6.6
HS	1/14/2013	25m	DG ≤ 15m	-	1.4	-	-	16.6	133	4.2	6.6
HS	2/28/2013	25m	DG ≤ 15m	-	1.2	13.6	52	12.8	112	3.5	6.6
HS	4/10/2013	25m	DG ≤ 15m	-	1.5	-	-	15.5	131	4.4	6.3
HS	7/24/2012	25s	DG ≤ 15m	-	1.2	25.9	90	25.1	48	1.0	4.5
HS	8/24/2012	25s	DG ≤ 15m	-	1.0	26.0	30	23.0	108	1.3	7.0
HS	9/7/2012	25s	DG ≤ 15m	-	1.2	-	-	25.1	189	1.1	6.4
HS	11/14/2012	25s	DG ≤ 15m	-	1.5	-	-	17.4	145	1.3	6.8
HS	1/14/2013	25s	DG ≤ 15m	-	1.3	-	-	16.2	151	5.6	6.4
HS	2/28/2013	25s	DG ≤ 15m	-	1.2	13.2	122	12.6	157	4.6	6.6
HS	4/10/2013	25s	DG ≤ 15m	-	1.5	-	-	16.3	135	2.5	6.2
HS	7/24/2012	26d	DG ≤ 15m	-	1.1	28.2	84	25.7	144	1.1	6.3
HS	8/24/2012	26d	DG ≤ 15m	-	1.0	26.0	88	24.1	112	1.9	6.7
HS	9/7/2012	26d	DG ≤ 15m	-	1.3	-	-	25.5	112	3.2	6.2
HS	11/14/2012	26d	DG ≤ 15m	-	1.5	-	-	18.8	108	1.5	6.4
HS	1/14/2013	26d	DG ≤ 15m	-	1.4	-	-	16.2	115	6.6	7.2
HS	2/28/2013	26d	DG ≤ 15m	-	1.2	13.2	68	12.8	86	4.9	6.2
HS	4/10/2013	26d	DG ≤ 15m	-	1.6	-	-	15.7	95	5.9	5.9
HS	7/24/2012	26s	DG ≤ 15m	-	1.2	28.0	33	26.3	83	1.7	6.1

HS	8/24/2012	26s	DG ≤ 15m	-	1.1	26.2	14	23.0	40	1.9	6.6
HS	9/7/2012	26s	DG ≤ 15m	-	1.3	-	-	25.4	42	3.6	5.8
HS	11/14/2012	26s	DG ≤ 15m	-	1.5	-	-	18.5	39	5.7	6.7
HS	1/14/2013	26s	DG ≤ 15m	-	1.4	-	-	16.0	24	6.9	7.3
HS	2/28/2013	26s	DG ≤ 15m	-	1.2	13.2	7	12.5	67	6.5	6.7
HS	4/10/2013	26s	DG ≤ 15m	-	1.6	-	-	16.5	24	7.2	6.2
HS	6/22/2012	23	DG ≥ 140m	6.8	1.0	23.4	18	-	-	-	-
HS	7/24/2012	23	DG ≥ 140m	7.2	0.5	28.5	14	27.2	56	1.2	5.9
HS	8/24/2012	23	DG ≥ 140m	7.3	0.5	26.5	5	23.8	45	1.7	5.3
HS	9/7/2012	23	DG ≥ 140m	7.2	0.6	-	-	26.0	57	1.8	5.8
HS	11/14/2012	23	DG ≥ 140m	7.0	0.8	-	-	18.3	45	3.5	6.6
HS	1/14/2013	23	DG ≥ 140m	7.1	0.7	-	-	15.3	43	6.3	6.7
HS	2/28/2013	23	DG ≥ 140m	7.2	0.6	12.4	0	12.1	76	4.9	6.3
HS	4/10/2013	23	DG ≥ 140m	6.9	0.8	-	-	16.3	36	4.5	6.0
HS	6/22/2012	Drainage Ditch north end of site	DG ≥ 160m	-	-	24.6	151	-	-	-	-
HS	7/24/2012	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	26.2	93	1.4	4.5
HS	8/24/2012	Drainage Ditch north end of site	DG ≥ 160m	-	-	23.7	22	22.8	66	1.9	5.0

HS	9/7/2012	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	-	-	-	-
HS	11/14/2012	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	-	-	-	-
HS	1/14/2013	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	16.9	116	4.0	6.4
HS	2/28/2013	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	11.4	135	6.4	6.0
HS	4/10/2013	Drainage Ditch north end of site	DG ≥ 160m	-	-	-	-	21.3	165	10.4	6.5
HS	6/22/2012	21	DG ≥ 40m	6.6	1.6	22.4	59	-	-	-	-
HS	7/24/2012	21	DG ≥ 40m	7.0	1.1	27.0	46	25.4	111	1.2	5.0
HS	8/24/2012	21	DG ≥ 40m	7.1	1.0	26.0	49	22.2	110	1.5	5.6
HS	9/7/2012	21	DG ≥ 40m	7.0	1.2	-	-	24.6	133	1.6	6.2

HS	11/14/2012	21	DG ≥ 40m	6.7	1.4	-	-	18.1	92	5.3	6.7
HS	1/14/2013	21	DG ≥ 40m	6.8	1.3	-	-	16.3	123	6.6	7.1
HS	2/28/2013	21	DG ≥ 40m	7.0	1.2	13.6	76	11.5	78	4.9	6.1
HS	4/10/2013	21	DG ≥ 40m	6.7	1.5	-	-	15.6	109	2.0	6.8
HS	6/22/2012	22d	DG ≥ 80m	5.1	2.9	21.0	1	-	-	-	-
HS	7/24/2012	22d	DG ≥ 80m	7.0	1.0	27.2	69	26.3	113	1.4	5.6
HS	8/24/2012	22d	DG ≥ 80m	7.1	0.9	26.5	55	23.2	123	1.7	6.5
HS	9/7/2012	22d	DG ≥ 80m	6.9	1.0	-	-	25.3	180	1.8	6.2
HS	11/14/2012	22d	DG ≥ 80m	6.7	1.2	-	-	18.8	159	4.3	6.4
HS	12/21/2012	22d	DG ≥ 80m	6.9	1.1	16.4	116	-	-	-	-
HS	1/14/2013	22d	DG ≥ 80m	6.8	1.1	-	-	16.4	147	5.3	6.3
HS	2/28/2013	22d	DG ≥ 80m	6.8	1.1	13.0	90	12.1	21	6.5	6.2
HS	4/10/2013	22d	DG ≥ 80m	6.7	1.3	-	-	16.2	123	5.3	6.5
HS	6/22/2012	22s	DG ≥ 80m	5.8	2.1	21.9	11	-	-	-	-
HS	7/24/2012	22s	DG ≥ 80m	7.0	0.9	25.6	29	22.3	34	1.5	5.6
HS	8/24/2012	22s	DG ≥ 80m	5.9	2.1	26.0	23	23.5	29	1.7	6.2
HS	9/7/2012	22s	DG ≥ 80m	7.0	1.0	-	-	26.0	38	2.2	6.0
HS	11/14/2012	22s	DG ≥ 80m	6.7	1.2	-	-	17.5	15	4.9	6.7
HS	1/14/2013	22s	DG ≥ 80m	6.8	1.1	-	-	15.2	20	8.4	7.1
HS	2/28/2013	22s	DG ≥ 80m	7.0	1.0	12.7	0	12.6	89	4.5	6.4
HS	4/10/2013	22s	DG ≥ 80m	6.7	1.3	-	-	15.6	16	8.2	6.9
HS	6/22/2012	10	OSP	6.3	2.0	22.1	3	-	-	-	-
HS	7/24/2012	10	OSP	6.7	1.6	26.6	1	26.7	38	1.7	4.9
HS	8/24/2012	10	OSP	7.3	1.1	26.0	-	23.6	24	2.6	5.3
HS	9/7/2012	10	OSP	7.0	1.3	-	-	26.0	62	5.8	6.4
HS	11/14/2012	10	OSP	6.7	1.6	-	-	17.5	28	2.4	5.8
HS	1/14/2013	10	OSP	6.9	1.4	-	-	16.5	22	8.0	6.4
HS	2/28/2013	10	OSP	7.0	1.3	13.2	0	12.6	51	7.6	5.8

HS	4/10/2013	10	OSP	6.7	1.6	-	-	16.0	28	7.7	6.0
HS	7/24/2012	27d	OSP	-	1.1	26.5	1	25.6	35	1.0	6.6
HS	8/24/2012	27d	OSP	-	0.9	26.0	-	23.3	11	2.7	6.1
HS	9/7/2012	27d	OSP	-	1.2	-	-	26.0	52	2.8	6.0
HS	11/14/2012	27d	OSP	-	1.4	-	-	17.5	89	1.7	6.2
HS	1/14/2013	27d	OSP	-	1.3	-	-	15.4	697	5.4	5.5
HS	2/28/2013	27d	OSP	-	1.1	12.9	332	12.8	540	5.8	5.6
HS	4/10/2013	27d	OSP	-	1.5	-	-	15.3	515	4.1	5.8
HS	7/24/2012	27m	OSP	-	1.1	26.0	2	25.1	36	1.6	6.8
HS	8/24/2012	27m	OSP	-	0.7	26.0	-	23.5	18	1.9	5.9
HS	9/7/2012	27m	OSP	-	0.9	-	-	25.3	31	2.2	6.0
HS	11/14/2012	27m	OSP	-	1.4	-	-	17.4	60	1.8	6.1
HS	1/14/2013	27m	OSP	-	1.3	-	-	15.1	167	5.3	6.0
HS	2/28/2013	27m	OSP	-	1.1	12.7	90	12.2	109	6.2	5.5
HS	4/10/2013	27m	OSP	-	1.4	-	-	15.3	113	6.2	6.0
HS	7/24/2012	27s	OSP	-	1.2	27.0	2	26.7	39	1.2	6.5
HS	8/24/2012	27s	OSP	-	1.0	26.0	-	22.1	10	2.3	5.0
HS	9/7/2012	27s	OSP	-	1.1	-	-	25.1	37	1.6	5.5
HS	11/14/2012	27s	OSP	-	1.4	-	-	17.6	24	4.9	6.1
HS	1/14/2013	27s	OSP	-	1.3	-	-	14.8	29	6.9	5.8
HS	2/28/2013	27s	OSP	-	1.1	12.7	1	11.5	30	6.6	4.9
HS	4/10/2013	27s	OSP	-	1.5	-	-	15.4	25	5.7	6.2

Table E2 Environmental Readings (collected using an YSI Pro).

High School (Site: HS)

Environmental Readings				TLC Meter	YSI		YSI Pro			
Site	Date	Sample Number	Location of Piezometer	DTW (m)	Temp (^{0}C)	EC (µS/cm)	pH	NO_3-N (mg/L)	NH_4-N (mg/L)	Cl (mg/L)
HS	2/28/2013	Tank	-	-	-	1033	-	52.0	50.0	200.0
HS	7/24/2012	1d	BG	0.78	27	126	5.2	0.6	8.2	7.4
HS	8/24/2012	1d	BG	0.62	26	76.5	5.3	0.8	1.4	3.4
HS	2/28/2013	1d	BG	0.86	13.2	472	-	0.1	5.5	74.0
HS	7/24/2012	1s	BG	0.75	26.5	103	5.0	0.2	0.5	9.5
HS	8/24/2012	1s	BG	0.61	25.7	48.5	5.0	0.5	0.7	3.5
HS	2/28/2013	1s	BG	0.83	12.9	183	-	0.2	0.4	6.4
HS	7/24/2012	2	BG	0.82	23	35	5.6	0.3	0.3	7.4
HS	8/24/2012	2	BG	1.28	25.2	76	4.8	0.8	0.4	7.5
HS	2/28/2013	2	BG	0.73	13.4	82	-	0.1	0.2	14.0
HS	7/24/2012	3	BG	1.04	24.6	29	5.4	0.3	0.5	0.9
HS	8/24/2012	3	BG	1.74	25.4	25	5.5	0.8	0.4	2.9
HS	2/28/2013	3	BG	0.96	13.1	28	-	0.1	0.1	3.0
HS	7/24/2012	4	BG	0.81	22.5	18	6.4	0.4	0.2	2.3
HS	8/24/2012	4	BG	0.67	25.2	19	5.4	0.7	0.9	1.5
HS	2/28/2013	4	BG	0.84	12.9	31	-	0.1	0.1	3.3
HS	7/24/2012	5d	BG	0.91	26	50	5.3	0.2	0.2	3.4

HS	8/24/2012	5d	BG	0.72	25.1	54	-	-	0.3	1.0
HS	2/28/2013	5d	BG	1.10	12.9	44	-	0.2	0.0	4.1
HS	7/24/2012	5s	BG	1.05	25.7	42	5.6	0.3	0.4	1.3
HS	8/24/2012	5s	BG	1.02	25.4	46	5.4	1.1	0.2	3.3
HS	7/24/2012	6	BG	1.17	23.6	60	5.3	0.4	0.8	5.4
HS	8/24/2012	6	BG	0.75	24.5	65	5.3	1.0	0.3	4.5
HS	2/28/2013	6	BG	1.02	12.9	65	-	0.7	0.1	10.0
HS	7/24/2012	7	BG	1.50	25	40	6.0	0.4	0.1	3.5
HS	8/24/2012	7	BG	0.98	24.9	61.5	5.9	0.5	0.1	7.2
HS	2/28/2013	7	BG	1.18	12.6	100	-	0.1	0.5	0.1
HS	7/24/2012	14	BG	1.05	25.5	18	5.9	0.3	0.4	0.5
HS	8/24/2012	14	BG	0.96	26.9	27	5.8	0.3	0.4	0.5
HS	2/28/2013	14	BG	1.18	13.6	117	-	0.2	0.4	52.0
HS	7/24/2012	8	DF	1.58	25.5	183	5.4	11.4	1.4	7.8
HS	8/24/2012	8	DF	1.41	26	69	5.2	2.8	0.4	3.5
HS	2/28/2013	8	DF	1.60	13.2	97	-	5.0	0.1	7.7
HS	7/24/2012	9	DF	1.54	24.9	49	5.7	1.4	0.4	1.9
HS	8/24/2012	9	DF	1.40	25.9	64	5.6	0.9	0.2	1.2
HS	2/28/2013	9	DF	1.65	13	69	-	1.2	0.1	2.0
HS	7/24/2012	11	DF	1.57	26.1	42	5.9	0.2	0.8	1.9
HS	8/24/2012	11	DF	1.42	25.9	37	5.4	0.5	0.5	1.0
HS	2/28/2013	11	DF	1.63	13.9	54	-	1.7	0.1	3.6
HS	7/24/2012	12	DF	1.60	26.1	293	6.9	13.5	1.1	11.9
HS	8/24/2012	12	DF	1.41	26.1	284	6.6	10.3	1.4	4.4
HS	2/28/2013	12	DF	1.60	14	460	-	40.9	0.5	50.0
HS	7/24/2012	13d	DF	1.49	26.1	1095	6.4	66.0	3.8	61.9
HS	8/24/2012	13d	DF	1.33	26.4	1075	6.2	9.5	2.3	71.5
HS	2/28/2013	13d	DF	1.54	14	819	-	170.0	1.8	80.0

HS	7/24/2012	13s	DF	1.60	26	838	6.5	55.2	1.6	41.6
HS	8/24/2012	13s	DF	1.34	26.4	362	6.4	66.4	0.9	14.3
HS	2/28/2013	13s	DF	1.54	13.9	479	-	100.0	0.4	63.0
HS	7/24/2012	15	DF	1.37	26.4	174	6.9	8.3	1.1	13.6
HS	8/24/2012	15	DF	1.17	26.2	158	6.4	2.5	1.0	3.8
HS	2/28/2013	15	DF	1.42	13.9	396	-	78.3	0.3	44.0
HS	7/24/2012	16	DF	1.37	25.9	70	6.2	3.6	0.3	5.3
HS	8/24/2012	16	DF	1.77	25.2	32	5.1	0.3	0.3	1.7
HS	2/28/2013	16	DF	1.42	13.6	224	-	20.8	0.2	11.0
HS	7/24/2012	17	DF	1.36	26.1	508	6.9	27.7	3.0	32.7
HS	8/24/2012	17	DF	1.19	26	303	6.4	26.8	1.6	14.4
HS	2/28/2013	17	DF	1.39	13.6	791	-	188.0	1.0	101.0
HS	7/24/2012	18	DF	1.23	26.9	162	6.7	3.1	2.2	2.9
HS	2/28/2013	18	DF	1.30	13.2	320	-	111.3	0.3	14.0
HS	7/24/2012	24d	DF	1.37	29.6	224	6.8	4.2	1.5	4.5
HS	8/24/2012	24d	DF	1.19	26.5	143	6.5	8.1	1.1	2.6
HS	2/28/2013	24d	DF	1.37	13.9	478	-	77.0	0.3	69.0
HS	7/24/2012	24s	DF	1.34	26.1	270	6.7	13.2	1.5	12.5
HS	8/24/2012	24s	DF	1.16	26.4	188	6.3	2.6	1.0	4.9
HS	2/28/2013	24s	DF	1.37	13.5	190	-	5.8	0.3	5.1
HS	7/24/2012	20	DG	1.23	22.5	54	5.9	1.4	0.1	2.0
HS	8/24/2012	20	DG	1.04	26.6	47	5.8	0.5	0.9	1.2
HS	2/28/2013	20	DG	1.21	13.2	33	-	0.1	0.0	0.8
HS	2/28/2013	19	DG OSP	1.12	13	38	-	0.4	0.0	1.5
HS	7/24/2012	25d	DG<15m	1.17	27.9	6.5	6.8	2.0	0.9	6.3
HS	8/24/2012	25d	DG<15m	1.00	26.4	203	6.8	1.6	1.3	5.0
HS	2/28/2013	25d	DG<15m	1.17	13.7	565	-	88.0	0.6	81.0
HS	7/24/2012	25s	DG<15m	1.20	25.9	4.54	6.5	1.6	0.5	2.6

HS	8/24/2012	25s	DG<15m	0.98	26	108	6.6	2.2	2.0	3.7
HS	2/28/2013	25s	DG<15m	1.17	13.2	157	-	2.3	0.2	7.1
HS	7/24/2012	26d	DG<15m	1.14	28.2	144	6.1	2.0	1.6	3.5
HS	8/24/2012	26d	DG<15m	0.99	26	112	6.2	0.9	0.9	5.8
HS	2/28/2013	26d	DG<15m	1.21	13.2	86	-	2.1	0.1	5.7
HS	7/24/2012	26s	DG<15m	1.16	28	83	6.6	0.8	0.4	1.9
HS	8/24/2012	26s	DG<15m	1.11	26.2	40	5.9	0.4	0.4	1.8
HS	2/28/2013	26s	DG<15m	1.21	13.2	67	-	0.8	0.0	4.2
HS	7/24/2012	25m	DG<15m	1.14	25.1	5.13	7.1	1.9	0.7	1.8
HS	8/24/2012	25m	DG<15m	1.01	26	112	6.5	1.6	1.3	0.8
HS	2/28/2013	25m	DG<15m	1.17	13.6	112	-	1.2	0.2	3.1
HS	7/24/2012	23	DG>140	0.53	28.5	56	6.0	0.7	1.0	0.4
HS	8/24/2012	23	DG>140	0.49	26.5	45	5.6	0.5	2.1	1.1
HS	2/28/2013	23	DG>140	0.61	12.4	76	-	0.2	0.1	0.9
HS	7/24/2012	21	DG>40	1.14	27	111	6.1	1.8	0.6	2.2
HS	8/24/2012	21	DG>40	1.04	26	110	6.0	2.7	0.7	4.1
HS	2/28/2013	21	DG>40	1.23	13.6	78	-	0.7	0.1	1.4
HS	7/24/2012	22d	DG>80m	0.96	27.2	113	7.1	1.4	0.5	2.0
HS	8/24/2012	22d	DG>80m	0.85	26.5	123	6.6	3.4	0.2	0.6
HS	2/28/2013	22d	DG>80m	1.11	13	21	-	0.2	0.0	1.2
HS	7/24/2012	22s	DG>80m	0.91	25.6	34	6.4	0.3	0.8	0.3
HS	8/24/2012	22s	DG>80m	2.07	26	29	6.0	0.7	1.1	0.7
HS	2/28/2013	22s	DG>80m	0.99	12.7	89	-	1.3	0.0	1.9
HS	7/24/2012	10	OSP	1.58	26.6	38	5.3	0.2	0.4	0.8
HS	8/24/2012	10	OSP	1.05	26	24	5.4	0.6	0.4	1.1
HS	2/28/2013	10	OSP	1.33	13.2	51	-	0.5	0.1	4.7
HS	7/24/2012	27d	OSP	1.10	26.5	35	6.4	1.4	0.3	1.0
HS	8/24/2012	27d	OSP	0.91	26	11	5.6	0.7	0.3	1.1

HS	2/28/2013	27d	OSP	1.08	12.9	540	-	67.0	0.7	100.0
HS	7/24/2012	27s	OSP	1.19	27	39	5.8	0.5	0.1	1.0
HS	8/24/2012	27s	OSP	0.98	26	10	5.7	1.1	2.5	1.1
HS	2/28/2013	27s	OSP	1.08	12.7	30	-	0.1	0.1	1.6
HS	7/24/2012	27m	OSP	1.08	26	36	6.2	0.8	0.1	1.4
HS	8/24/2012	27m	OSP	0.75	26	18	5.7	0.8	0.3	1.2
HS	2/28/2013	27m	OSP	1.08	12.7	109	-	0.6	0.2	14.0
HS	8/24/2012	Drainage Ditch		-	23.7	66	5.3	4.8	0.4	1.5
HS	2/28/2013	Drainage Ditch		-	-	135	-	1.9	0.1	2.2

Elementary School (Site: EM)

Environmental Readings				TLC Meter	YSI		YSI Pro			
Site	Date	Sample Number	Location of Piezometer	DTW (m)	Temp (^{0}C)	EC (µS/cm)	pH	NO_3-N (mg/L)	NH_4-N (mg/L)	Cl (mg/L)
ES	2/27/2013	Tank/D-Box	-	-	14.6	1005	6.9	3.8	50.0	280.0
ES	8/27/2012	1	BG	3.61	23.3	167	6.6	1.7	1.7	9.4
ES	2/27/2013	1	BG	0.85	11.6	32	7.8	0.3	0.8	0.6
ES	7/27/2012	2	BG	3.95	24.1	110	5.0	0.7	0.3	7.1
ES	8/27/2012	2	BG	4.13	23.4	148	5.8	2.3	3.8	4.7
ES	2/27/2013	2	BG	4.15	14.2	83	6.7	0.5	0.1	3.1
ES	7/27/2012	3	BG	3.95	24.5	158	5.4	0.3	0.3	10.8
ES	8/27/2012	3	BG	4.30	23.2	103	5.7	0.5	0.9	6.7
ES	2/27/2013	3	BG	4.13	14.1	92	4.8	0.2	0.1	3.1
ES	8/27/2012	9	BG	5.32	23.6	79	5.7	0.4	2.3	1.6
ES	2/27/2013	9	BG	5.32	15.0	52	7.4	0.2	0.1	2.8
ES	7/27/2012	4	DF	3.97	23.3	318	6.1	7.6	0.6	18.3
ES	8/27/2012	4	DF	4.16	22.4	425	6.9	17.6	3.0	35.7
ES	2/27/2013	4	DF	4.04	14.8	529	5.3	77.6	0.6	82.0
ES	8/27/2012	5	DF	4.16	23.2	652	6.1	23.6	1.3	71.7
ES	2/27/2013	5	DF	4.06	14.3	127	6.3	8.2	0.3	13.0
ES	7/27/2012	6	DF	4.83	22.9	767	5.6	44.2	0.7	68.8
ES	8/27/2012	6	DF	4.96	22.6	733	5.9	41.4	1.2	72.9
ES	2/27/2013	6	DF	4.84	14.8	606	5.7	78.0	0.4	95.0
ES	8/27/2012	7	DF	6.16	21.5	1187	7.1	1.8	18.7	100.6
ES	2/27/2013	7	DF	6.25	15.8	883	6.6	3.4	0.2	178.0
ES	8/27/2012	8	DF	6.10	20.6	898	7.3	14.2	1.0	70.7

ES	2/27/2013	8	DF	6.13	15.5	823	6.1	79.0	0.2	128.0
ES	7/27/2012	10	DF	3.97	23.2	281	6.2	5.9	0.4	18.5
ES	8/27/2012	10	DF	4.13	22.9	399	6.5	16.5	1.2	27.3
ES	2/27/2013	10	DF	4.02	14.7	688	6.0	89.0	0.7	161.0
ES	8/27/2012	14	DF	6.31	20.5	1010	7.1	21.0	0.6	67.6
ES	2/27/2013	14	DF	6.14	16.4	7174	6.8	32.1	0.1	115.0
ES	8/27/2012	11d	DF	6.93	20.2	404	7.3	1.2	0.5	12.1
ES	2/27/2013	11d	DF	6.96	15.9	286	7.2	0.4	0.1	10.0
ES	8/27/2012	11s	DF	6.90	20.0	432	7.3	2.2	0.7	14.0
ES	2/27/2013	11s	DF	6.95	14.6	311	7.1	0.3	0.0	15.1
ES	7/27/2012	13d	DF	4.55	22.5	423	6.1	37.5	1.0	61.4
ES	8/27/2012	13d	DF	4.63	23.0	708	6.4	36.5	-	-
ES	2/27/2013	13d	DF	4.85	14.7	392	6.0	57.2	0.2	62.0
ES	7/27/2012	13s	DF	4.75	22.9	365	-	-	-	69.6
ES	2/27/2013	13s	DF	4.60	14.9	433	6.1	69.0	0.5	81.0
ES	8/27/2012	12d	DG<15m	7.12	20.0	502	7.3	1.5	0.8	44.3
ES	2/27/2013	12d	DG<15m	7.10	15.8	402	7.1	0.8	0.0	44.0
ES	8/27/2012	12s	DG<15m	7.06	20.7	590	7.0	4.2	0.5	32.0
ES	8/27/2012	15	DG>20m	7.09	20.4	143	7.7	1.4	1.5	3.9
ES	2/27/2013	15	DG>20m	7.13	15.4	245	7.2	2.4	0.1	10.9
ES	7/27/2012	16	DG>30m	0.83	23.9	369	6.9	1.2	0.1	7.1
ES	8/27/2012	16	DG>30m	0.91	21.7	356	7.1	0.8	0.4	10.0
ES	2/27/2013	16	DG>30m	0.76	12.5	249	7.0	0.2	0.1	1.7
ES	7/27/2012	17	DG>30m	0.83	22.9	630	6.6	1.2	0.6	42.9
ES	8/27/2012	17	DG>30m	0.91	22.0	639	6.8	1.1	0.5	54.2
ES	2/27/2013	17	DG>30m	0.72	11.3	282	6.8	0.2	0.1	56.0
ES	7/27/2012	18	DG>30m	1.24	23.9	691	6.9	6.2	0.3	25.5
ES	8/27/2012	18	DG>30m	1.26	22.4	715	6.9	9.2	0.5	34.3

ES	2/27/2013	18	DG>30m	1.23	11.5	466	6.7	6.2	0.1	51.0
ES	7/27/2012	Spring 1	DG>30m	-	-	449	6.8	5.7	0.2	16.8
ES	8/27/2012	Spring 1	DG>30m	-	19.5	466	6.8	9.7	0.4	32.5
ES	2/27/2013	Spring 1	DG>30m	-	16.6	361	7.2	3.4	0.1	28.0
ES	7/27/2012	Spring 2	DG>40m	-	-	442	6.8	10.6	0.2	15.5
ES	2/27/2013	Spring 2	DG>40m	-	14.5	79	6.9	6.5	0.1	27.0
ES	7/27/2012	Spring/Stream	DG>40m	-	-	125	6.9	3.4	0.1	8.7
ES	2/27/2013	Spring/Stream	DG>40m	-	12.0	325	6.9	6.6	0.1	20.0
ES	7/27/2012	19	DG>50m	1.65	-	352	6.5	2.6	1.4	14.2
ES	2/27/2013	19	DG>50m	1.39	9.6	156	7.2	1.0	0.1	2.0
ES	7/27/2012	20	DG>50m	0.91	-	444	1.4	6.6	20.0	-
ES	2/27/2013	20	DG>50m	0.85	10.2	198	6.9	0.8	0.3	2.4
ES	7/27/2012	5m Downstream	DG>50m	-	-	129	6.8	4.0	0.1	9.1
ES	2/27/2013	5m Downstream	DG>50m	-	11.3	91	7.3	3.8	0.1	8.8
ES	7/27/2012	5m Upstream	DG>50m	-	-	128	7..01	2.9	0.1	10.0
ES	2/27/2013	5m Upstream	DG>50m	-	11.6	329	7.2	2.2	0.1	12.7
ES	2/27/2013	21	DG>70m	1.21	10.1	252	7.0	2.9	0.1	0.4

Education Center (Site: EC)

Environmental Readings				TLC Meter	YSI		YSI Pro			
Site	Date	Sample Number	Location of Piezometer	DTW (m)	Temp (^{0}C)	EC (µS/cm)	pH	NO_3-N (mg/L)	NH_4-N (mg/L)	Cl (mg/L)
EC	1/30/2013	Tank	-	-	16.8	1066	7.3	23.0	170.0	400.0
EC	2/25/2013	Tank	-	-	9.6	828	5.8	4.2	56.0	86.0
EC	8/15/2012	1d	BG	2.6	23.7	50.5	5.7	0.6	1.8	3.4
EC	1/30/2013	1d	BG	3.0	16.7	124	5.4	5.4	0.9	0.6
EC	2/25/2013	1d	BG	2.8	14.9	23	7.2	0.3	16.6	0.1
EC	8/15/2012	1s	BG	2.6	24.9	124	4.8	0.3	2.1	3.0
EC	1/30/2013	1s	BG	3.0	17.2	39	5.9	0.6	2.5	1.4
EC	2/25/2013	1s	BG	2.7	14.0	92	5.8	2.3	2.0	1.0
EC	8/15/2012	3	DF	3.4	23.8	100.5	5.6	3.2	2.4	3.5
EC	1/30/2013	3	DF	3.6	17.4	115	5.9	5.1	1.2	23.0
EC	2/25/2013	3	DF	3.4	13.8	103	5.2	5.3	0.3	7.6
EC	8/15/2012	2d	DF	2.9	23.3	117.5	5.8	2.2	2.4	2.4
EC	1/30/2013	2d	DF	3.3	17.4	107	5.0	5.2	2.0	8.8
EC	2/25/2013	2d	DF	3.0	14.3	74	5.0	2.7	0.8	2.2
EC	8/15/2012	2s	DF	2.9	23.5	247	4.4	14.3	2.4	6.1
EC	1/30/2013	2s	DF	3.3	17.2	116	5.6	6.9	2.0	24.1
EC	2/25/2013	2s	DF	3.0	13.5	129	5.2.	7.8	0.7	6.7
EC	8/15/2012	4	DG<15m	3.5	22.4	72.5	6.2	0.9	3.5	3.2
EC	1/30/2013	4	DG<15m	3.7	17.5	114	5.4	5.2	1.0	27.8
EC	2/25/2013	4	DG<15m	3.5	13.4	108	4.9	3.8	0.3	10.5
EC	8/15/2012	5	DG<15m	3.2	22.0	164	5.7	2.4	3.8	2.4
EC	1/30/2013	5	DG<15m	3.4	17.3	129	4.7	7.8	1.1	18.0
EC	2/25/2013	5	DG<15m	3.2	14.1	115	4.5	4.4	0.3	11.7

EC	8/15/2012	10	DG>20m	2.2	21.5	122	4.7	4.6	0.6	4.9
EC	1/30/2013	10	DG>20m	2.4	15.0	96	4.6	3.4	1.4	22.0
EC	2/25/2013	10	DG>20m	2.3	11.7	85	4.8	2.2	0.4	4.1
EC	8/15/2012	13	DG>20m	1.6	22.5	134	5.3	4.0	1.1	3.4
EC	1/30/2013	13	DG>20m	1.6	14.1	108	4.5	4.0	0.5	23.0
EC	2/25/2013	13	DG>20m	1.4	12.1	99	4.5	3.6	0.4	2.8
EC	8/15/2012	11d	DG>20m	1.0	21.9	118	5.8	4.9	1.6	2.3
EC	1/30/2013	11d	DG>20m	1.0	14.1	111	4.4	5.1	0.9	13.0
EC	2/25/2013	11d	DG>20m	0.9	12.1	100	4.4	4.2	0.2	6.0
EC	8/15/2012	11s	DG>20m	0.9	22.0	121.5	5.3	4.9	1.1	3.8
EC	1/30/2013	11s	DG>20m	1.0	14.1	105	4.5	5.3	1.4	17.0
EC	2/25/2013	11s	DG>20m	0.8	11.5	97	4.4	4.7	0.3	5.3
EC	8/15/2012	12d	DG>20m	2.7	19.8	131	5.2	2.1	0.8	4.4
EC	1/30/2013	12d	DG>20m	2.5	15.5	117	4.6	5.3	0.8	32.0
EC	2/25/2013	12d	DG>20m	2.2	13.4	106	4.6	3.6	0.2	5.8
EC	8/15/2012	12s	DG>20m	1.6	21.2	111	4.7	4.0	1.0	3.1
EC	1/30/2013	12s	DG>20m	1.6	14.1	104	4.4	3.0	0.6	23.0
EC	2/25/2013	12s	DG>20m	1.3	12.0	95	4.4	4.9	0.6	2.3
EC	8/15/2012	6	DG>30m	2.0	21.7	128.5	5.7	1.6	2.1	6.7
EC	1/30/2013	6	DG>30m	1.8	15.4	160	4.6	1.9	0.3	120.0
EC	2/25/2013	6	DG>30m	1.9	12.6	131	4.6	0.4	0.1	56.0
EC	8/15/2012	7	DG>30m	2.0	22.2	108	4.8	1.2	1.1	7.2
EC	1/30/2013	7	DG>30m	1.9	15.4	134	5.1	5.3	1.4	95.0
EC	2/25/2013	7	DG>30m	1.9	12.6	116	4.8	0.2	0.7	30.5
EC	8/15/2012	8	DG>30m	2.0	21.3	161	4.3	2.3	1.7	4.5
EC	1/30/2013	8	DG>30m	2.0	16.1	126	4.7	2.4	0.8	35.0
EC	2/25/2013	8	DG>30m	1.8	12.1	110	4.2	1.4	0.2	8.1
EC	1/30/2013	9	DG>30m	1.4	15.9	66	4.5	1.0	0.3	28.0

EC	2/25/2013	9	DG>30m	1.2	12.0	55	4.8	0.4	0.1	12.3

Residential 100 (Site: Res-100)

Environmental Readings				TLC Meter	YSI		YSI Pro			
Site	Date	Sample Number	Location of Piezometer	DTW (m)	Temp (^{0}C)	EC (µS/cm)	pH	NO_3-N (mg/L)	NH_4-N (mg/L)	Cl (mg/L)
Res-100	1/25/2013	Tank	-	-	-	557	6.6	-	14.0	300.0
Res-100	1/25/2013	101	BG	0.9	12.3	192	4.5	4.6	5.0	5.4
Res-100	1/25/2013	102	BG	0.7	12.7	-	4.8	5.9	1.4	13.7
Res-100	1/25/2013	103	DF	0.4	10.9	164	6.0	2.0	15.8	30.6
Res-100	1/25/2013	104	DF	0.0	8.5	206	6.3	28.3	20.8	112.0
Res-100	1/25/2013	105	DF	0.5	10.4	181	6.5	30.7	30.0	40.2
Res-100	1/25/2013	110d	DF	0.5	10.8	219	6.3	36.4	18.7	111.0
Res-100	1/25/2013	110s	DF	0.5	9.6	333	6.3	27.9	42.0	108.0
Res-100	1/25/2013	106	DG<15M	0.8	12.0	49	5.6	2.7	1.7	39.0
Res-100	1/25/2013	107d	DG<15M	1.2	12.6	54	5.8	31.4	3.4	20.9
Res-100	1/25/2013	107s	DG<15M	1.2	11.3	83	5.6	34.6	10.0	19.9
Res-100	1/25/2013	108d	DG<15M	1.3	11.7	144	5.6	9.5	5.6	82.7
Res-100	1/25/2013	108m	DG<15M	1.4	9.7	146	6.3	68.4	8.1	82.1
Res-100	1/25/2013	108s	DG<15M	dry	dry	dry	dry	dry	dry	dry
Res-100	1/25/2013	109d	DG<15M	1.0	11.0	202	6.1	60.5	15.0	72.0
Res-100	1/25/2013	109s	DG<15M	1.1	9.9	163	6.0	50.9	5.0	63.5
Res-100	1/25/2013	Stream	DG>15m	-	12.5	148	5.9	22.0	1.8	37.0

Table E3: Average Water Level and Hydraulic Head (determined using the TLC meter to collect water level)

High School (Site: HS)

Site	Piezometer ID	Location	Elevation (m)	Average HH (mamsl)	Average DTW (m)	Sample Number (n)
HS	1d	BG	7.9	6.95	0.9	9
HS	1s	BG	7.9	6.96	0.9	8
HS	2	BG	7.7	6.76	1.0	8
HS	3	BG	8.1	6.86	1.2	8
HS	4	BG	7.9	6.87	1.0	8
HS	5d	BG	8.0	6.95	1.0	8
HS	5s	BG	8.0	6.81	1.2	8
HS	6	BG	8.1	6.89	1.2	8
HS	7	BG	8.2	6.83	1.4	10
HS	14	BG	8.2	6.93	1.2	8
HS	8	DF	8.6	6.94	1.7	8
HS	9	DF	8.6	6.95	1.7	8
HS	11	DF	8.6	6.86	1.8	9
HS	12	DF	7.9	6.19	1.7	8
HS	13d	DF	8.6	6.95	1.7	9
HS	13s	DF	8.6	6.91	1.7	10
HS	15	DF	8.4	6.89	1.5	8
HS	16	DF	8.5	6.86	1.6	8
HS	17	DF	8.4	6.88	1.5	9
HS	18	DF	8.3	6.88	1.5	7
HS	24d	DF	8.4	6.88	1.5	8
HS	24s	DF	8.4	6.94	1.4	7
HS	20	DG	8.2	6.89	1.3	8
HS	19	DG OSP	8.2	6.89	1.3	5
HS	23	DG ≥ 140m	7.8	7.08	0.7	8
HS	21	DG ≥ 40m	8.2	6.88	1.3	8
HS	22d	DG ≥ 80m	8.0	6.67	1.3	9
HS	22s	DG ≥ 80m	8.0	6.62	1.3	8
HS	10	OSP	8.3	6.83	1.5	8
Total Average				**6.86**	**1.34**	**236.00**

Elementary School (Site: ES)

Site	Piezometer ID	Location	Elevation (m)	Average HH (mamsl)	Average DTW (m)	Sample Number (n)
ES	1	BG	12.2	8.9	3.2	8
ES	2	BG	12.1	8.0	4.1	8
ES	3	BG	12.1	7.9	4.2	8
ES	9	BG	11.8	6.5	5.3	8
ES	4	DF	12.1	8.1	4.0	8
ES	5	DF	11.8	7.8	4.0	7
ES	6	DF	12.0	7.2	4.8	8
ES	7	DF	12.0	5.9	6.1	7
ES	10	DF	12.0	8.0	4.0	9
ES	11d	DF	12.0	5.1	6.9	7
ES	11s	DF	12.0	5.1	6.9	8
ES	13d	DF	12.0	7.3	4.7	8
ES	13s	DF	12.0	7.4	4.7	7
ES	14	DF	11.9	6.0	5.9	8
ES	12d	DG $\leq$ 15m	12.1	4.6	7.5	7
ES	12s	DG $\leq$ 15m	12.1	5.1	7.1	5
ES	15	DG $\geq$ 20m	12.0	4.9	7.1	8
ES	16	DG $\geq$ 30m	5.4	4.6	0.9	8
ES	17	DG $\geq$ 30m	5.3	4.4	0.9	8
ES	18	DG $\geq$ 30m	5.8	4.6	1.2	8
ES	8	OSP	11.6	5.5	6.1	8
ES	16	DG $\geq$ 30m	5.4	4.6	0.9	8
ES	17	DG $\geq$ 30m	5.3	4.4	0.9	8
ES	18	DG $\geq$ 30m	5.8	4.6	1.2	9
Total Average				**6.1**	**4.3**	**186**

Education Center (EC)

Site	Piezometer ID	Location	Elevation (m)	Average HH (mamsl)	Average DTW (m)	Sample Number (n)
EC	1d	BG	13.5	11.01	2.5	12
EC	1s	BG	13.5	10.73	2.8	8
EC	2d	DF	12.8	9.87	2.0	12
EC	2s	DF	12.8	9.73	3.1	8
EC	3	DF	13.1	9.60	3.5	13
EC	4	DG ≤ 15m	12.9	9.14	3.8	12
EC	5	DG ≤ 15m	12.8	9.56	3.2	12
EC	6	DG ≥ 30m	6.8	4.92	1.9	13
EC	7	DG ≥ 30m	6.7	4.83	1.9	12
EC	8	DG ≥ 30m	6.6	4.65	1.9	12
EC	9	DG ≥ 30m	6.3	4.88	1.4	13
Total Average				**8.08**	**2.5**	**127**

Residential 100 (Site: Res-100)

Site	Piezometer ID	Location	Elevation (m)	Average HH (mamsl)	Average DTW (m)	Sample Number (n)
Res-100	101	BG	13.7	12.83	0.9	6
Res-100	102	BG	13.7	12.97	0.7	6
Res-100	103	DF	13.2	12.71	0.5	6
Res-100	104	DF	12.9	12.65	0.2	6
Res-100	105	DF	13.0	12.53	0.5	5
Res-100	110d	DF	12.9	12.38	0.5	6
Res-100	110s	DF	12.9	12.41	0.5	6
Res-100	106	DG ≤ 15m	12.3	11.56	0.7	6
Res-100	107d	DG ≤ 15m	12.5	11.40	1.1	6
Res-100	107s	DG ≤ 15m	12.5	11.39	1.1	6
Res-100	108d	DG ≤ 15m	12.4	11.13	1.3	6
Res-100	108m	DG ≤ 15m	12.4	11.08	1.3	6
Res-100	109d	DG ≤ 15m	12.4	11.38	1.0	6
Res-100	109s	DG ≤ 15m	12.4	11.30	1.1	6
Total Average				**11.98**	**0.81**	**83.00**

Table E4: BG and DF Average Water Levels

Appendix Table E4 shows the environmental readings collected throughout the study period. The data includes: background (BG) sample number (n), BG average water level, average BG groundwater specific conductivity (µS/cm), the drainfield (DF) sample number (n), average DF water level, average DF groundwater specific conductivity (µS/cm).

Environmental Readings						
Site	**BG Sample Number (n)**	**BG Average Water Level (mbgs)**	**BG µS/cm**	**DF Sample Number (n)**	**DF Average Water Level (mbgs)**	**DF µS/cm**
Residential 100	10	0.80	181	29	0.44	280
Education Center	22	2.59	79	34	3.18	99
High School	76	1.11	66	99	1.61	362
Elementary School	25	4.52	86	59	5.24	593

Table E5: Recharge and Discharge Areas

The nested piezometers or piezometers located less than 3 m apart were used to assess the vertical groundwater flow at each site and to determine recharge and discharge areas. The sample number for each piezometer was shown below the "n" column.

Site	Piezometer	Depth to Screen Bottom (m)	Average Water Level (mbgs)	Average Hydraulic Head (mamsl)	n	Recharge or Discharge
High School	1s	1.95	0.94	6.96	8	Recharge
	1d	3.61	0.95	6.95	9	
	13s	2.50	1.7	6.91	10	Discharge
	13d	3.60	1.66	6.95	9	
	22s	1.95	1.34	6.62	8	Discharge
	22d	3.56	1.29	6.67	9	
	25s	2.74	1.27	7.03	7	Recharge
	25m	3.64	1.27	7.03	7	
	25d	4.66	1.28	7.01	7	
Elementary School	2	4.75	4.1	7.99	8	Recharge
	3	5.96	4.2	7.92	8	
	11s	8.69	6.82	5.12	8	Recharge
	11d	9.60	6.92	5.09	7	
	12s	9.62	7.1	5.05	5	Recharge
	12d	10.53	7.5	4.60	7	
	13s	5.77	4.68	7.37	7	Recharge
	13d	5.87	4.69	7.34	8	
Education Center	1s	3.90	2.8	10.73	8	Discharge
	1d	5.39	2.5	11.01	12	
	2s	3.84	3.1	9.73	8	Discharge
	2d	4.42	2	9.87	12	
	11s	2.30	0.89	8.91	8	Recharge
	11d	3.50	0.99	8.81	8	
	12s	3.00	1.77	7.49	8	Recharge
	12d	3.90	2.31	8.03	8	
Residential 100	110s	1.58	0.49	12.41	6	Recharge
	110d	2.46	0.52	12.38	6	
	107s	1.50	1.11	11.39	6	Discharge
	107d	2.50	1.1	11.40	6	
	108m	1.90	1.32	11.08	6	Discharge
	108d	2.40	1.27	11.13	6	
	109s	1.60	1.1	11.30	6	Discharge
	109d	2.10	1	11.38	6	

Appendix Table F: CCR Resistivity Values

Table F1: Objective 1 Background (BG) and Drainfield (DF) CCR values used in Figures 8-12 and Appendix Q. *Refer to Appendix P to view resistivity depth sections and corresponding CCR survey resistivity collection methodology also discussed in the Methods section. Ω.m stands for resistivity and GW stands for groundwater. The groundwater specific conductivity values were collected using an YSI except at the education center when a TLC meter was used on 3/23/2012.

High School (HS), Elementary School (ES), Education Center (EC), and Residential 100, 300, and 400 (Res-100, Res-300, Res-400) sites' BG and DF Values									
Site	Date Sampled	Transect ID	Piezometer ID	Depth to GW (m)	Depth to Bottom of Screen (m)	GW Specific Conductivity (µS/cm)	Ω.m Selected at Screened Interval	Log (Ω.m)	Location of Piezometer
Res-100	7/16/2012	T3	101	0.8	2.48	212	19	1.3	BG
Res-100	11/16/2012	T3	101	0.7	2.48	174	126	2.1	BG
Res-100	3/27/2013	T3	101	0.9	2.48	228	117	2.1	BG
Res-100	7/16/2012	T3	102	0.7	2.32	171	152	2.2	BG
Res-100	11/16/2012	T3	102	0.6	2.32	316	161	2.2	BG
Res-100	3/27/2013	T3	102	0.7	2.32	184	98	2.0	BG
Res-300	9/17/2012	T1	300	0.8	3.44	65	214	2.3	BG
Res-400	9/17/2012	T1	403	1.7	4.15	169	652	2.8	BG
EC	3/23/2012	T1	1d	3.0	5.39	28	221	2.3	BG
EC	9/4/2012	T1	1d	2.4	5.39	175	167	2.2	BG
EC	11/29/2012	T1	1d	2.8	5.39	80	93	2.0	BG
EC	4/17/2013	T1	1d	2.9	5.39	38	189	2.3	BG
EC	9/4/2012	T1	1s	2.4	3.90	158	186	2.3	BG
EC	11/29/2012	T1	1s	2.8	3.90	128	92	2.0	BG
EC	4/17/2013	T1	1s	2.9	3.90	142	178	2.3	BG

ES	9/10/2012	T1	2	3.7	4.75	97	4121	3.6	BG
ES	11/19/2012	T1	2	4.1	4.75	104	3564	3.6	BG
ES	3/25/2013	T1	2	4.1	4.75	123	2601	3.4	BG
ES	9/10/2012	T1	3	3.7	5.96	139	827	2.9	BG
ES	11/19/2012	T1	3	4.8	5.96	131	3577	3.6	BG
ES	3/25/2013	T1	3	4.1	5.96	119	327	2.5	BG
ES	9/10/2012	T3	9	4.8	6.80	64	498	2.7	BG
ES	9/10/2012	T5	9	4.8	6.80	64	364	2.6	BG
HS	4/10/2013	T1	7	1.5	2.40	33	2012	3.3	BG
HS	9/7/2012	T1	7	1.2	2.40	57	2893	3.5	BG
HS	11/14/2012	T1	7	1.5	2.40	79	3006	3.5	BG
HS	4/10/2013	T1	1d	1.0	3.61	82	1684	3.2	BG
HS	9/7/2012	T1	1d	0.9	3.61	107	1048	3.0	BG
HS	4/10/2013	T1	1s	1.0	1.95	295	650	2.8	BG
HS	9/7/2012	T1	1s	0.8	1.95	126	1283	3.1	BG
HS	11/14/2012	T1	1s	1.2	1.95	147	612	2.8	BG
HS	9/7/2012	T2	2	0.7	2.33	80	543	2.7	BG
HS	9/7/2012	T2	3	1.1	2.30	34	417	2.6	BG
HS	9/7/2012	T2	5	1.0	2.41	51	434	2.6	BG
HS	9/7/2012	T3	14	1.2	2.19	32	4747	3.7	BG
HS	9/7/2012	T3	7	1.2	2.40	57	2009	3.3	BG
Res-100	7/16/2012	T2	103	0.3	1.57	248	73	1.9	DF
Res-100	11/16/2012	T2	103	0.3	1.57	201	107	2.0	DF
Res-100	3/27/2013	T2	103	0.5	1.57	186	174	2.2	DF
Res-100	7/16/2012	T2	104	0.0	2.25	226	128	2.1	DF
Res-100	11/16/2012	T2	104	0.0	2.25	138	41	1.6	DF
Res-100	3/27/2013	T2	104	0.4	2.25	279	81	1.9	DF
Res-100	7/16/2012	T2	105	0.2	1.22	313	92	2.0	DF

Res-100	3/27/2013	T2	105	0.5	1.22	239	74	1.9	DF
Res-100	7/16/2012	T2	110d	0.4	2.46	69	74	1.9	DF
Res-100	11/16/2012	T2	110d	0.5	2.46	372	137	2.1	DF
Res-100	3/27/2013	T2	110d	0.6	2.46	117	129	2.1	DF
Res-100	7/16/2012	T2	110s	0.4	1.58	600	73	1.9	DF
Res-100	11/16/2012	T2	110s	0.3	1.58	484	101	2.0	DF
Res-100	3/27/2013	T2	110s	0.5	1.58	551	119	2.1	DF
Res-300	9/7/2012	T1	301	0.9	1.68	76	90	2.0	DF
Res-300	9/7/2012	T1	302	0.9	2.39	101	94	2.0	DF
Res-300	9/7/2012	T1	303	1.1	2.52	112	84	1.9	DF
Res-300	9/7/2012	T1	305	1.0	2.83	96	91	2.0	DF
Res-400	9/7/2012	T1	401	1.7	4.13	126	737	2.9	DF
Res-400	9/7/2012	T1	402	1.5	3.98	116	160	2.2	DF
EC	3/23/2012	T1	3	4.0	4.51	64	42	1.6	DF
EC	9/4/2012	T1	3	3.0	4.51	113	156	2.2	DF
EC	11/29/2012	T1	3	3.6	4.51	152	281	2.4	DF
EC	4/17/2013	T1	3	3.6	4.51	130	48	1.7	DF
EC	3/23/2012	T3	3	4.0	4.51	64	202	2.3	DF
EC	9/4/2012	T3	3	3.0	4.51	113	131	2.1	DF
EC	11/29/2012	T3	3	3.6	4.51	152	29	1.5	DF
EC	4/17/2013	T3	3	3.6	4.51	130	268	2.4	DF
EC	3/23/2012	T3	2d	3.2	4.42	65	628	2.8	DF
EC	9/4/2012	T3	2d	2.6	4.42	100	160	2.2	DF
EC	11/29/2012	T3	2d	3.2	4.42	138	39	1.6	DF
EC	4/17/2013	T3	2d	3.3	4.42	129	614	2.8	DF
EC	9/4/2012	T3	2s	2.6	3.84	284	283	2.5	DF
EC	11/29/2012	T3	2s	3.2	3.84	188	161	2.2	DF
EC	4/17/2013	T3	2s	3.3	3.84	159	615	2.8	DF

ES	9/10/2012	T1	10	3.600	4.60	597	4	0.64	DF
ES	11/19/2012	T1	10	4.1	4.60	567	112	2.05	DF
ES	3/25/2013	T1	10	4.0	4.60	867	63	1.80	DF
ES	9/10/2012	T1	4	3.6	4.98	465	129	2.11	DF
ES	11/19/2012	T1	4	4.1	4.98	361	383	2.58	DF
ES	3/25/2013	T1	4	4.1	4.98	745	193	2.29	DF
ES	9/10/2012	T1	13d	4.5	5.87	683	37	1.57	DF
ES	11/19/2012	T1	13d	4.7	5.87	518	50	1.70	DF
ES	3/25/2013	T1	13d	4.8	5.87	487	127	2.10	DF
ES	9/10/2012	T1	13s	4.3	5.77	727	37	1.57	DF
ES	11/19/2012	T1	13s	4.9	5.77	465	50	1.70	DF
ES	3/25/2013	T1	13s	4.5	5.77	618	127	2.10	DF
ES	9/10/2012	T2	6	4.5	6.43	698	151	2.18	DF
ES	9/10/2012	T2	7	6.0	6.74	1036	14	1.15	DF
ES	9/10/2012	T2	14	6.0	7.24	838	8	0.90	DF
ES	9/10/2012	T6	4	3.6	4.98	465	170	2.23	DF
ES	9/10/2012	T6	5	3.7	5.17	615	202	2.31	DF
HS	4/10/2013	T1	8	1.9	2.44	111	100	2.0	DF
HS	9/7/2012	T1	8	1.7	2.44	87	77	1.9	DF
HS	11/14/2012	T1	8	1.6	2.44	213	102	2.0	DF
HS	4/10/2013	T1	12	2.0	2.50	497	66	1.8	DF
HS	9/7/2012	T1	12	1.7	2.50	336	137	2.1	DF
HS	11/14/2012	T1	12	1.6	2.50	234	106	2.0	DF
HS	4/10/2013	T1	18	1.6	2.47	515	69	1.8	DF
HS	9/7/2012	T1	18	1.4	2.47	184	183	2.3	DF
HS	11/14/2012	T1	18	1.6	2.47	390	69	1.8	DF
HS	4/10/2013	T1	13d	1.9	3.60	1000	54	1.7	DF
HS	9/7/2012	T1	13d	1.6	3.60	802	51	1.7	DF

HS	11/14/2012	T1	13d	1.6	3.60	726	35	1.5	DF
HS	4/10/2013	T1	13s	1.9	2.50	763	61	1.8	DF
HS	9/7/2012	T1	13s	1.6	2.50	363	136	2.1	DF
HS	11/14/2012	T1	13s	1.6	2.50	453	61	1.8	DF
HS	9/7/2012	T4	24d	1.4	3.33	527	120	2.1	DF
HS	9/7/2012	T4	24s	1.4	2.43	240	109	2.0	DF
HS	4/10/2013	T1	15	1.7	2.45	703	57	1.8	DF
HS	9/7/2012	T1	15	1.4	2.45	181	146	2.2	DF
HS	11/14/2012	T1	15	1.7	2.45	260	81	1.9	DF
HS	4/10/2013	T1	24d	1.7	3.33	650	37	1.6	DF
HS	9/7/2012	T1	24d	1.4	3.33	527	122	2.1	DF
HS	11/14/2012	T1	24d	1.7	3.33	437	75	1.9	DF
HS	4/10/2013	T1	24s	1.7	2.43	526	43	1.6	DF
HS	9/7/2012	T1	24s	1.4	2.43	240	182	2.3	DF
HS	11/14/2012	T1	24s	1.7	2.43	323	75	1.9	DF
HS	9/7/2012	T2	11	1.6	2.34	39	2852	3.5	DF
HS	9/7/2012	T6	8	1.7	2.44	87	1659	3.2	DF
HS	9/7/2012	T6	9	1.6	2.48	76	2007	3.3	DF

Table F2. Objective 2 Background (BG), Drainfield (DF), and Downgradient (DG) CCR values used in Figures 13-16 and Appendix R. *Refer to Appendix P to view resistivity depth sections and data.

High School (HS), Education Center (EC), and Residential 100, and 200 (Res-100 and Res-200) sites' BG, DF, and DG Values									
Site	**Date Sampled**	**Transect ID**	**Piezometer ID**	**Depth to GW (m)**	**Depth to Bottom of Screen (m)**	**GW Specific Conductivity (µS/cm)**	**Ω.m Selected at Screened Interval**	**Log (Ω.m)**	**Location of Piezometer**
Res-100	7/16/2012	T3	101	0.8	2.48	212	19	1.3	BG

Res-100	11/16/2012	T3	101	0.7	2.48	174	126	2.1	BG
Res-100	3/27/2013	T3	101	0.9	2.48	228	117	2.1	BG
Res-100	7/16/2012	T3	102	0.7	2.32	171	152	2.2	BG
Res-100	11/16/2012	T3	102	0.6	2.32	316	161	2.2	BG
Res-100	3/27/2013	T3	102	0.7	2.32	184	98	2.0	BG
EC	3/23/2012	T1	1d	3.0	5.39	28	221	2.3	BG
EC	9/4/2012	T1	1d	2.4	5.39	175	167	2.2	BG
EC	11/29/2012	T1	1d	2.8	5.39	80	93	2.0	BG
EC	4/17/2013	T1	1d	2.9	5.39	38	189	2.3	BG
EC	9/4/2012	T1	1s	2.4	3.90	158	186	2.3	BG
EC	11/29/2012	T1	1s	2.8	3.90	128	92	2.0	BG
EC	4/17/2013	T1	1s	2.9	3.90	142	178	2.3	BG
HS	4/10/2013	T1	7	1.5	2.40	33	2012	3.3	BG
HS	9/7/2012	T1	7	1.2	2.40	57	2893	3.5	BG
HS	11/14/2012	T1	7	1.5	2.40	79	3006	3.5	BG
HS	4/10/2013	T1	1d	1.0	3.61	82	1684	3.2	BG
HS	9/7/2012	T1	1d	0.9	3.61	107	1048	3.0	BG
HS	4/10/2013	T1	1s	1.0	1.95	295	650	2.8	BG
HS	9/7/2012	T1	1s	0.8	1.95	126	1283	3.1	BG
HS	11/14/2012	T1	1s	1.2	1.95	147	612	2.8	BG
HS	9/7/2012	T2	2	0.7	2.33	80	543	2.7	BG
HS	9/7/2012	T2	3	1.1	2.30	34	417	2.6	BG
HS	9/7/2012	T2	5	1.0	2.41	51	434	2.6	BG
HS	9/7/2012	T3	14	1.2	2.19	32	4747	3.7	BG
HS	9/7/2012	T3	7	1.2	2.40	57	2009	3.3	BG
Res-100	7/16/2012	T2	103	0.3	1.57	248	73	1.9	DF
Res-100	11/16/2012	T2	103	0.3	1.57	201	107	2.0	DF
Res-100	3/27/2013	T2	103	0.5	1.57	186	174	2.2	DF

Res-100	7/16/2012	T2	104	0.0	2.25	226	128	2.1	DF
Res-100	11/16/2012	T2	104	0.0	2.25	138	41	1.6	DF
Res-100	3/27/2013	T2	104	0.4	2.25	279	81	1.9	DF
Res-100	7/16/2012	T2	105	0.2	1.22	313	92	2.0	DF
Res-100	3/27/2013	T2	105	0.5	1.22	239	74	1.9	DF
Res-100	7/16/2012	T2	110d	0.4	2.46	69	74	1.9	DF
Res-100	11/16/2012	T2	110d	0.5	2.46	372	137	2.1	DF
Res-100	3/27/2013	T2	110d	0.6	2.46	117	129	2.1	DF
Res-100	7/16/2012	T2	110s	0.4	1.58	600	73	1.9	DF
Res-100	11/16/2012	T2	110s	0.3	1.58	484	101	2.0	DF
Res-100	3/27/2013	T2	110s	0.5	1.58	551	119	2.1	DF
EC	3/23/2012	T1	3	4.0	4.51	64	42	1.6	DF
EC	9/4/2012	T1	3	3.0	4.51	113	156	2.2	DF
EC	11/29/2012	T1	3	3.6	4.51	152	281	2.4	DF
EC	4/17/2013	T1	3	3.6	4.51	130	48	1.7	DF
EC	3/23/2012	T3	3	4.0	4.51	64	202	2.3	DF
EC	9/4/2012	T3	3	3.0	4.51	113	131	2.1	DF
EC	11/29/2012	T3	3	3.6	4.51	152	29	1.5	DF
EC	4/17/2013	T3	3	3.6	4.51	130	268	2.4	DF
EC	3/23/2012	T3	2d	3.2	4.42	65	628	2.8	DF
EC	9/4/2012	T3	2d	2.6	4.42	100	160	2.2	DF
EC	11/29/2012	T3	2d	3.2	4.42	138	39	1.6	DF
EC	4/17/2013	T3	2d	3.3	4.42	129	614	2.8	DF
EC	9/4/2012	T3	2s	2.6	3.84	284	283	2.5	DF
EC	11/29/2012	T3	2s	3.2	3.84	188	161	2.2	DF
EC	4/17/2013	T3	2s	3.3	3.84	159	615	2.8	DF
HS	4/10/2013	T1	8	1.9	2.44	111	100	2.0	DF
HS	9/7/2012	T1	8	1.7	2.44	87	77	1.9	DF

HS	11/14/2012	T1	8	1.6	2.44	213	102	2.0	DF
HS	4/10/2013	T1	12	2.0	2.50	497	66	1.8	DF
HS	9/7/2012	T1	12	1.7	2.50	336	137	2.1	DF
HS	11/14/2012	T1	12	1.6	2.50	234	106	2.0	DF
HS	4/10/2013	T1	18	1.6	2.47	515	69	1.8	DF
HS	9/7/2012	T1	18	1.4	2.47	184	183	2.3	DF
HS	11/14/2012	T1	18	1.6	2.47	390	69	1.8	DF
HS	4/10/2013	T1	13d	1.9	3.60	1000	54	1.7	DF
HS	9/7/2012	T1	13d	1.6	3.60	802	51	1.7	DF
HS	11/14/2012	T1	13d	1.6	3.60	726	35	1.5	DF
HS	4/10/2013	T1	13s	1.9	2.50	763	61	1.8	DF
HS	9/7/2012	T1	13s	1.6	2.50	363	136	2.1	DF
HS	11/14/2012	T1	13s	1.6	2.50	453	61	1.8	DF
HS	9/7/2012	T4	24d	1.4	3.33	527	120	2.1	DF
HS	9/7/2012	T4	24s	1.4	2.43	240	109	2.0	DF
HS	4/10/2013	T1	15	1.7	2.45	703	57	1.8	DF
HS	9/7/2012	T1	15	1.4	2.45	181	146	2.2	DF
HS	11/14/2012	T1	15	1.7	2.45	260	81	1.9	DF
HS	4/10/2013	T1	24d	1.7	3.33	650	37	1.6	DF
HS	9/7/2012	T1	24d	1.4	3.33	527	122	2.1	DF
HS	11/14/2012	T1	24d	1.7	3.33	437	75	1.9	DF
HS	4/10/2013	T1	24s	1.7	2.43	526	43	1.6	DF
HS	9/7/2012	T1	24s	1.4	2.43	240	182	2.3	DF
HS	11/14/2012	T1	24s	1.7	2.43	323	75	1.9	DF
HS	9/7/2012	T2	11	1.6	2.34	39	2852	3.5	DF
HS	9/7/2012	T6	8	1.7	2.44	87	1659	3.2	DF
HS	9/7/2012	T6	9	1.6	2.48	76	2007	3.3	DF

Residential 100 (Res-100), Education Center (EC), High School (HS), and Residential 200 (Res-200) Downgradient CCR Values for Objective 2									
Site	**Date Sampled**	**Transect ID**	**Piezometer ID**	**Depth to GW (m)**	**Depth to Bottom of Screen (m)**	**Specific Conductivity (μS/cm)**	**Ω.m Selected at Screened Interval**	**Log (Ω.m)**	**DG Distance of Piezometer (m)**
EC	3/23/2012	T1	4	3.7	5.65	51	199	2.30	4
EC	9/4/2012	T1	4	3.2	5.65	120	87	1.94	4
EC	11/29/2012	T1	4	3.6	5.65	135	123	2.09	4
EC	4/17/2013	T1	4	3.7	5.65	103	33	1.52	4
EC	3/23/2012	T1	5	3.5	5.29	45	108	2.03	4
EC	9/4/2012	T1	5	2.9	5.29	159	86	1.93	4
EC	11/29/2012	T1	5	3.4	5.29	145	112.5	2.05	4
EC	4/17/2013	T1	5	3.5	5.29	143	25	1.40	4
EC	9/4/2012	T6	11d	0.6	3.5	138	67.85	1.83	19
EC	12/11/2012	T6	11d	1.0	3.5	90	57.39	1.76	19
EC	9/4/2012	T6	11s	0.6	2.3	140	84.05	1.92	19
EC	12/11/2012	T6	11s	0.9	2.3	161	64.695	1.81	19
EC	9/4/2012	T6	12d	1.9	3.9	171	60.3	1.78	23
EC	12/11/2012	T6	12d	2.8	3.9	182	48.86	1.69	23
EC	9/4/2012	T6	12s	1.2	3	138	68.21	1.83	23
EC	12/11/2012	T6	12s	1.6	3	155	48.81	1.69	23
EC	9/4/2012	T6	13	1.2	3.1	140	74.52	1.87	26
EC	12/11/2012	T6	13	1.7	3.1	167	53.35	1.73	26
EC	9/4/2012	T5	7	1.2	2.7	130	393.29	2.59	36
EC	12/11/2012	T5	7	1.9	2.7	112	378.49	2.58	36
EC	9/4/2012	T5	6	2.0	2.5	87	428.27	2.63	39

EC	12/11/2012	T5	6	1.9	2.5	120	1154.7	3.06	39
Res-100	7/16/2012	T1	109d	1.0	2.1	100	123	2.09	10
Res-100	11/16/2012	T1	109d	0.9	2.1	218	116	2.06	10
Res-100	3/27/2013	T1	109d	1.0	2.1	254	66	1.82	10
Res-100	7/16/2012	T1	109s	1.0	1.6	307	93	1.97	10
Res-100	11/16/2012	T1	109s	1.0	1.6	295	116	2.06	10
Res-100	3/27/2013	T1	109s	1.1	1.6	199	74	1.87	10
Res-100	7/16/2012	T1	108d	1.1	2.4	434	85	1.93	11
Res-100	11/16/2012	T1	108d	1.3	2.4	222	76	1.88	11
Res-100	3/27/2013	T1	108d	1.3	2.4	413	156	2.19	11
Res-100	7/16/2012	T1	108m	1.1	1.9	328	41	1.61	11
Res-100	11/16/2012	T1	108m	1.3	1.9	265	76	1.88	11
Res-100	3/27/2013	T1	108m	1.3	1.9	187	125	2.10	11
Res-100	7/16/2012	T1	108s	1.0	1.2	326	46	1.66	11
Res-100	11/16/2012	T1	108s	dry	1.2	dry	dry	dry	11
Res-100	3/27/2013	T1	108s	dry	1.2	dry	dry	dry	11
Res-100	7/16/2012	T1	107d	1.0	2.5	131	99	2.00	13
Res-100	11/16/2012	T1	107d	1.0	2.5	112	118	2.07	13
Res-100	3/27/2013	T1	107d	1.2	2.5	68	203	2.31	13
Res-100	7/16/2012	T1	107s	1.0	1.50	156	69	1.84	13
Res-100	11/16/2012	T1	107s	1.0	1.50	142	93	1.97	13
Res-100	3/27/2013	T1	107s	1.2	1.50	112	118	2.07	13
Res-200	9/17/2012	T1	207d	0.5	2.26	100	105.00	2.02	24
Res-200	9/17/2012	T1	207s	0.7	1.45	355	83.00	1.92	24
Res-200	9/17/2012	T1	209d	0.5	2.07	205	90.00	1.95	24
Res-200	9/17/2012	T1	212d	0.5	2.09	162	126.00	2.10	24
Res-200	9/17/2012	T1	212s	0.9	1.31	574	125.00	2.10	24
Res-200	9/17/2012	T1	211	0.4	2.05	162	92.00	1.96	25

HS	9/7/2012	T1	25d	1.2	4.66	499	169	2.23	9
HS	11/14/2012	T1	25d	1.5	4.66	558	37	1.57	9
HS	4/10/2013	T1	25d	1.5	4.66	578	336	2.53	9
HS	9/7/2012	T1	25m	1.2	3.64	115	352	2.55	9
HS	11/14/2012	T1	25m	1.5	3.64	128	528	2.72	9
HS	4/10/2013	T1	25m	1.5	3.64	131	81	1.91	9
HS	9/7/2012	T1	25s	1.2	2.74	189	298	2.47	9
HS	11/14/2012	T1	25s	1.5	2.74	145	529	2.72	9
HS	4/10/2013	T1	25s	1.5	2.74	135	41	1.61	9
HS	9/7/2012	T1	21	1.2	2.41	133	504	2.70	41
HS	9/7/2012	T5	21	1.2	2.41	133	477	2.68	41
HS	11/14/2012	T1	21	1.4	2.41	92	772	2.89	41
HS	4/10/2013	T1	21	1.5	2.41	109	378	2.58	41
HS	9/7/2012	T1	22d	1.0	3.56	180	394	2.60	88
HS	11/14/2012	T1	22d	1.2	3.56	159	1388	3.14	88
HS	4/10/2013	T1	22d	1.3	3.56	123	654	2.82	88
HS	9/7/2012	T1	22s	1.0	1.95	38	2506	3.40	88
HS	11/14/2012	T1	22s	1.2	1.95	15	3246	3.51	88
HS	4/10/2013	T1	22s	1.3	1.95	16	2271	3.36	88
HS	9/7/2012	T1	23	0.6	1.79	57	2616	3.42	145
HS	11/14/2012	T1	23	0.8	1.79	45	2191	3.34	145
HS	4/10/2013	T1	23	0.8	1.79	36	4718	3.67	145

F3: OSP Values and Mann-Whitney Comparisons

Appendix Table F3A: Shows the education center (EC), Residential 100 (Res-100), Residential 200 (Res-200) and High School (HS) OSP piezometers. The data includes: the site, date sampled, transect the resistivity data were collected from, and the groundwater specific conductivity (µS/cm) and CCR survey resistivity (Ω.m) values collected at the piezometers. The OSP dataset (below) was an independent dataset and was not included in the background or drainfield datasets (Appendices: F1 and F2). Mann-Whitney comparisons of the OSP values with background and drainfield locations are provided below.

OSP Downgradient CCR Values									
Site	**Date Sampled**	**Transect ID**	**Piezometer ID**	**Depth to GW (m)**	**Depth to Bottom of Screen (m)**	**GW Specific Conductivity (µS/cm)**	**Ω.m Selected at Screened Interval**	**Log (Ω.m)**	**Location of Piezometer**
EC	9/4/2012	T6	10	1.3	3.4	138	69.3	1.84	DG OSP
EC	9/4/2012	T5	9	1.6	2.5	60	140.7	2.15	DG OSP
EC	9/4/2012	T5	8	1.5	3.8	184	541.6	2.73	DG OSP
EC	12/11/2012	T6	10	2.5	3.4	125	104.0	2.02	DG OSP
EC	12/11/2012	T5	9	1.4	2.5	76	181.8	2.26	DG OSP
EC	12/11/2012	T5	8	2.0	3.8	156	990.8	3.00	DG OSP
Res-100	7/16/2012	T1	106	0.6	2.37	85	334.0	2.52	DG OSP
Res-100	11/16/2012	T1	106	0.6	2.37	79	132.0	2.12	DG OSP
Res-100	3/27/2013	T1	106	0.8	2.37	60	230.0	2.36	DG OSP
Res-200	9/17/2012	T1	213	0.6	2.07	200	262.0	2.42	DG OSP
HS	9/7/2012	T2	19	1.1	2.21	63	1224.0	3.09	DG OSP
HS	9/7/2012	T2	27d	1.2	4.66	52	1796.0	3.25	DG OSP
HS	9/7/2012	T2	27m	0.9	3.64	31	3078.0	3.49	DG OSP
HS	9/7/2012	T2	10	1.3	2.52	62	3149.0	3.50	DG OSP
HS	9/7/2012	T2	27s	1.1	2.74	37	3470.0	3.54	DG OSP

Appendix Table F3B: shows the OSP groundwater specific conductivity and resistivity median values. The table also shows the Mann-Whitney Comparison p-values collected from OSP value comparisons with background and drainfield values. The p-values in bold are < 0.05 and indicate the datasets were significantly different.

Site	Location	Sample Number	Median Groundwater Specific Conductivity (µS/cm)	Median Ω.m	Mann-Whitney Comparison of BG vs. OSP p-values		Mann-Whitney Comparison of DF vs. OSP p-values	
					µS/cm	Ω.m	µS/cm	Ω.m
Pooled Data	BG	36	113	466	0.2458	0.8605	**0.0000**	**0.0000**
	DF	81	279	102				
	OSP	15	76	334				
Education Center	BG	7	128	178	0.8303	0.9431	0.9379	0.8457
	DF	15	130	161				
	OSP	6	132	161				
Residential 100	BG	6	198	122	**0.0282**	0.0933	**0.0198**	**0.0376**
	DF	14	244	96.3				
	OSP	3	79	230				
High School	BG	13	79	1283	0.5963	0.0654	**0.0000**	**0.0002**
	DF	29	363	81				
	OSP	15	76	334				

Appendix G: Outliers Objectives 1 and 2. Outliers were collected from the high school (HS), elementary school (ES), education center (EC), Residential 100 (Res-100), Residential 400 (Res-400), Residential 200 (Res-200). The µS/cm represents the groundwater specific conductivity values and the Ω.m represents the corresponding resistivity values collected from CCR surveys.

Table G1: Objective 1, Background vs. Drainfield outlier values collected from Figures 8-12 and Appendices Q. The column labeled Fig. references the figure numbers for the outliers listed in the table.

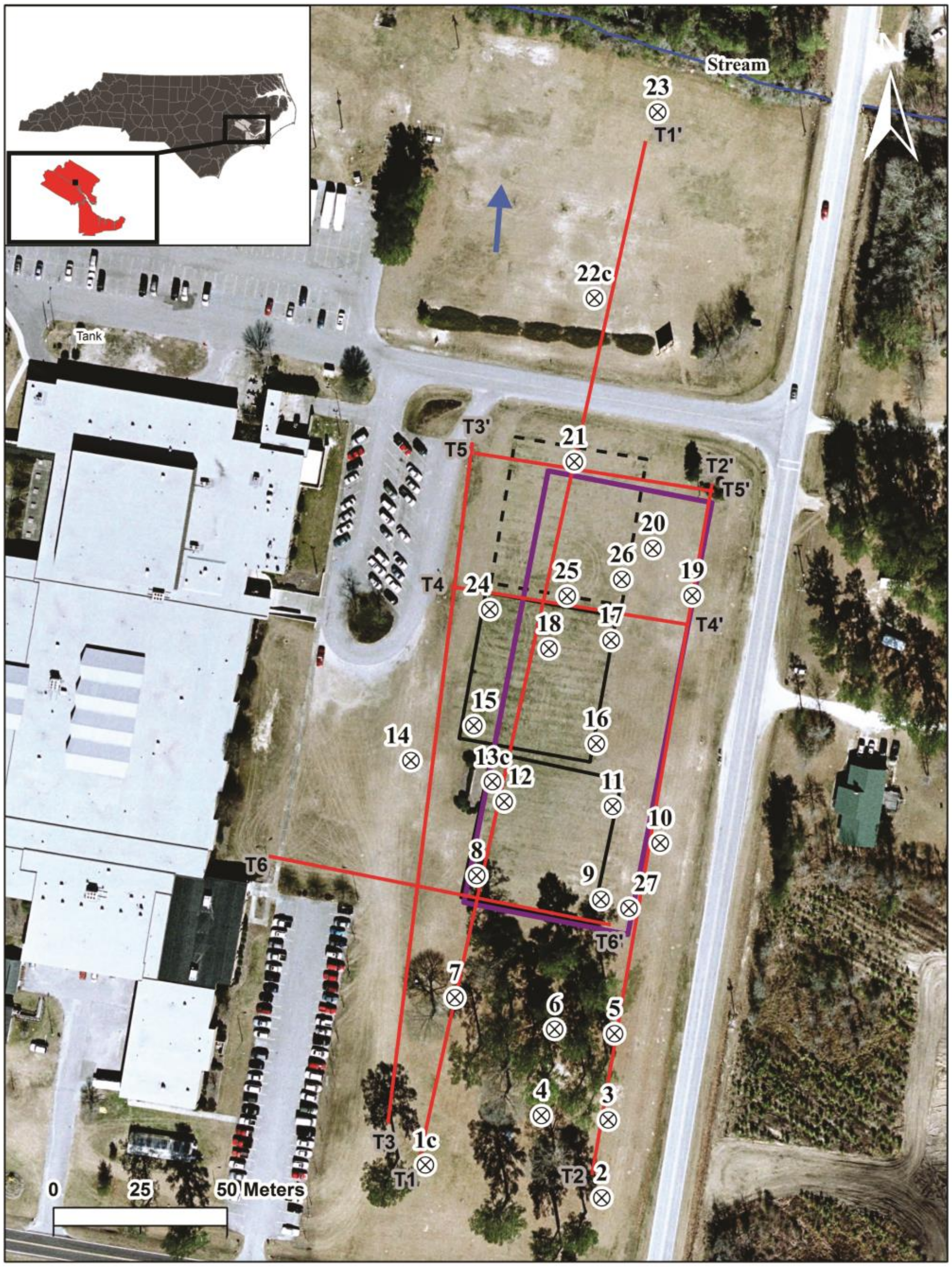
Value range of sectioned datasets	Site	Date Sampled	Transect ID	Piezometer ID	µS/cm	Ω.m	Log (Ω.m)	Location of Piezometer
Background	Res-100	7/16/2012	T3	101	212	18.6	1.3	BG
	HS	4/10/2012	T1	1s	295	650	2.8	BG
	HS	9/7/2012	T3	14	32	4747	3.7	BG
Ω.m < 250 µS/cm < 200	EC	3/23/2012	T1	3	64	42	0.9	DF
	HS	9/7/2012	T1	8	87	77	1.9	DF
	HS	4/10/2012	T1	8	111	100	2.0	DF
	EC	4/17/2013	T1	3	130	48	1.6	DF
	EC	11/29/2012	T3	2D	138	39.17	1.6	DF
	Res-100	11/16/2012	T2	104	138	41.45	1.6	DF
	EC	11/29/2012	T3	3	152	29.32	1.5	DF
Ω.m < 250 µS/cm > 200	Res-100	11/16/2012	T2	110s	484	100.5	2.0	DF
	Res-100	3/27/2013	T2	110s	551	118.9	2.1	DF
	Res-100	7/16/2012	T2	110s	600	73	1.9	DF
Ω.m > 250	EC	9/4/2012	T3	2S	284	282.9	2.5	DF
	ES	11/19/2012	T1	4	361	383	2.6	DF
	EC	4/17/2013	T3	2D	129	614.1	2.8	DF
	EC	4/17/2013	T3	2S	159	614.9	2.8	DF
	EC	3/23/2012	T3	2D	65	628.1	2.8	DF
	Res-400	9/7/2012	T1	401	126	737.0	2.9	DF
	HS	9/7/2012	T6	8	87	1659	3.2	DF
	HS	9/7/2012	T2	9	76	2007	3.3	DF
	HS	9/7/2012	T6	11	39	2852	3.5	DF

Table G2: Objective 2 Outlier values Appendix R groundwater specific conductivity (µS/cm) and resistivity (Ω.m) values.

Value range of sectioned datasets	Site	Date Sampled	Piezometer ID	Specific Conductivity (µS/cm)	Resistivity Value Selected at Screened Interval (Ω.m)	Log (Ω.m)	Location of Piezometer and Distance from DF (m)	Outliers selected from the Ω.m and µS/cm boxplots
Ω.m ≤ 250 µS/cm ≥ 200	Res-200	9/17/2012	207S	355	83	1.92	DG ≤ 15	µS/cm
	Res-100	3/27/2013	108D	413	156	2.19	DG ≤ 15	µS/cm
	Res-100	7/16/2012	108D	434	85	1.93	DG ≤ 15	µS/cm
	HS	9/7/2012	25D	499	169	2.23	DG 3-5	µS/cm
	HS	11/14/2012	25D	558	37	1.57	DG 3-5	µS/cm
	Res-200	9/17/2012	212S	574	125	2.10	DG ≤ 15	µS/cm
µS/cm ≥ 200	HS	4/10/2013	25D	578	336	2.53	DG 3-5	µS/cm
Ω.m ≥ 250 µS/cm ≤ 200	HS	11/14/2012	22S	15	3246	3.51		Ω.m
	HS	4/10/2013	22S	16	2271	3.36	DG ≥ 40	Ω.m
	HS	4/10/2013	23	36	4718	3.67	DG ≥ 40	Ω.m
	HS	9/7/2012	22S	38	2506	3.40	DG ≥ 40	Ω.m
	HS	11/14/2012	23	45	2191	3.34	DG ≥ 40	Ω.m
	HS	9/7/2012	23	57	2616	3.42	DG ≥ 40	Ω.m
	EC	12/11/2012	6	120	1155	3.06	DG ≥ 30	Ω.m
	HS	11/14/2012	22D	159	1388	3.14	DG ≥ 40	Ω.m

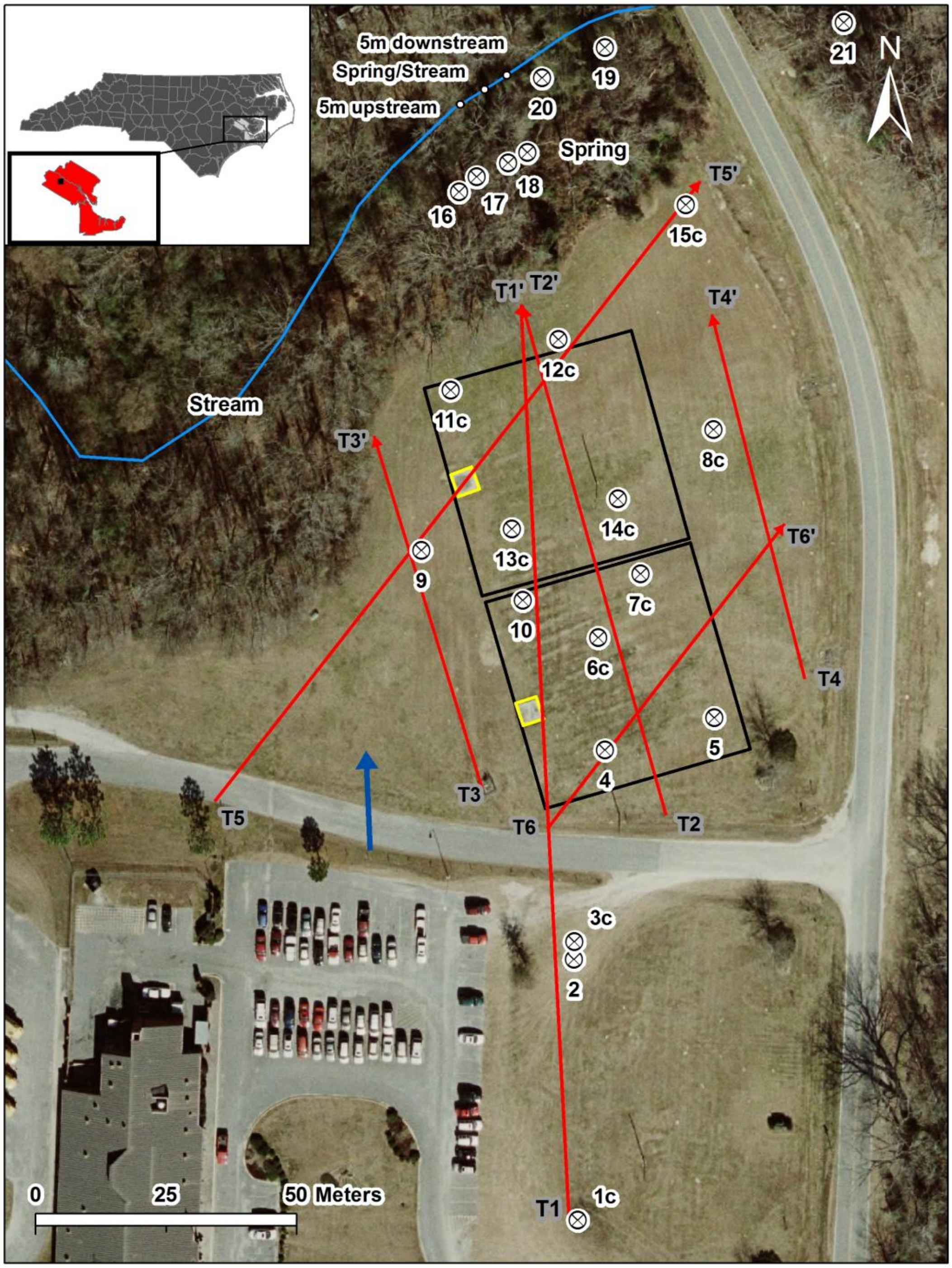
Appendix H: Geophysical Transects (both CCR and GPR)

High School



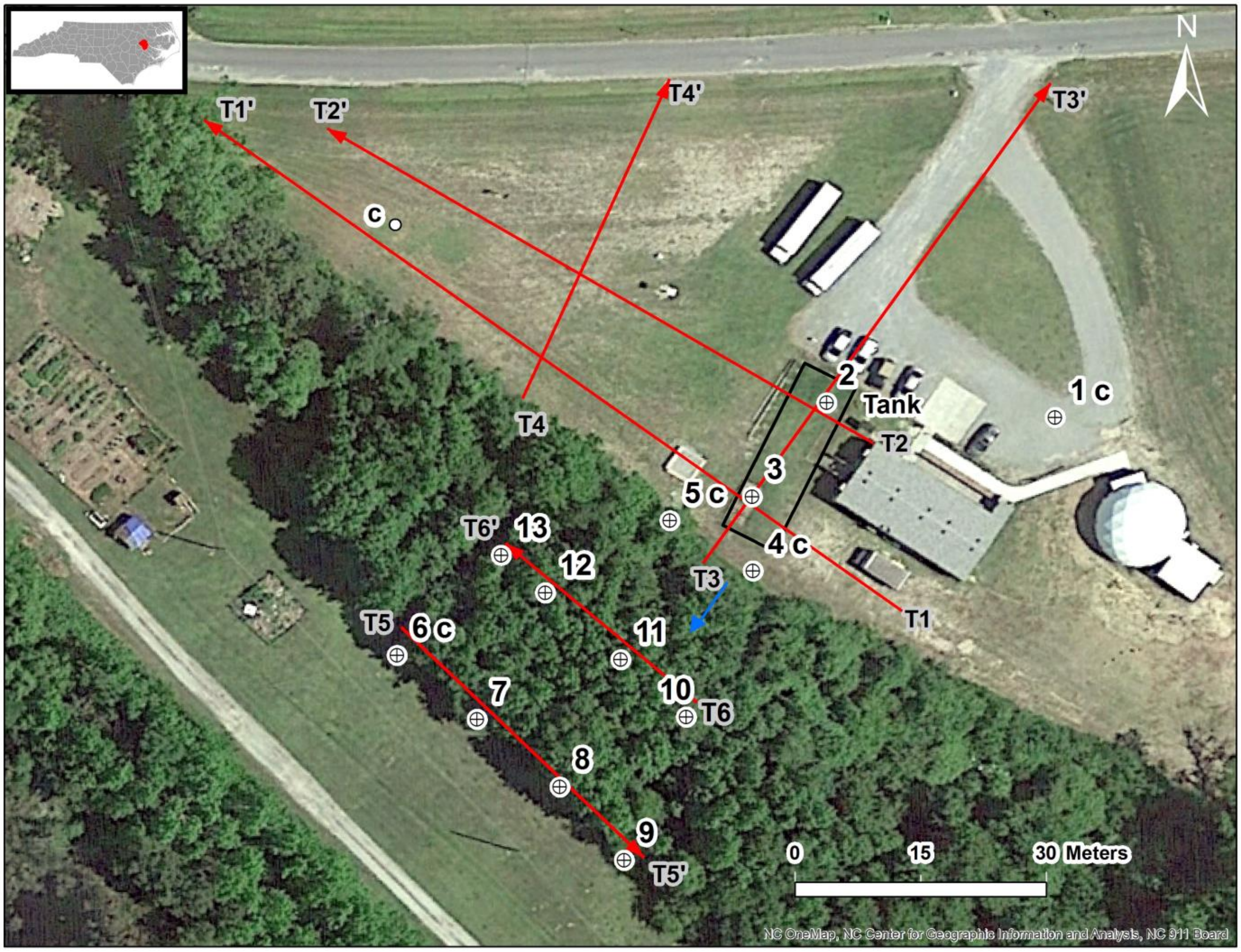
Appendix Figure H1 shows the High School transects (solid red lines) with corresponding transect ID numbers (black and grey font), the 3D survey area (purple box), the respective locations of the 2 active drainfields (solid black box), and the 1 de-activated drainfield (dashed black box).

Elementary School



Appendix Figure H2 shows the elementary school transects (solid red lines) with corresponding transect ID numbers (black and grey font), the 3D survey area (purple box), the respective locations of the 2 active drainfields (1 solid black box) and the locations of the distribution boxes (yellow squares).

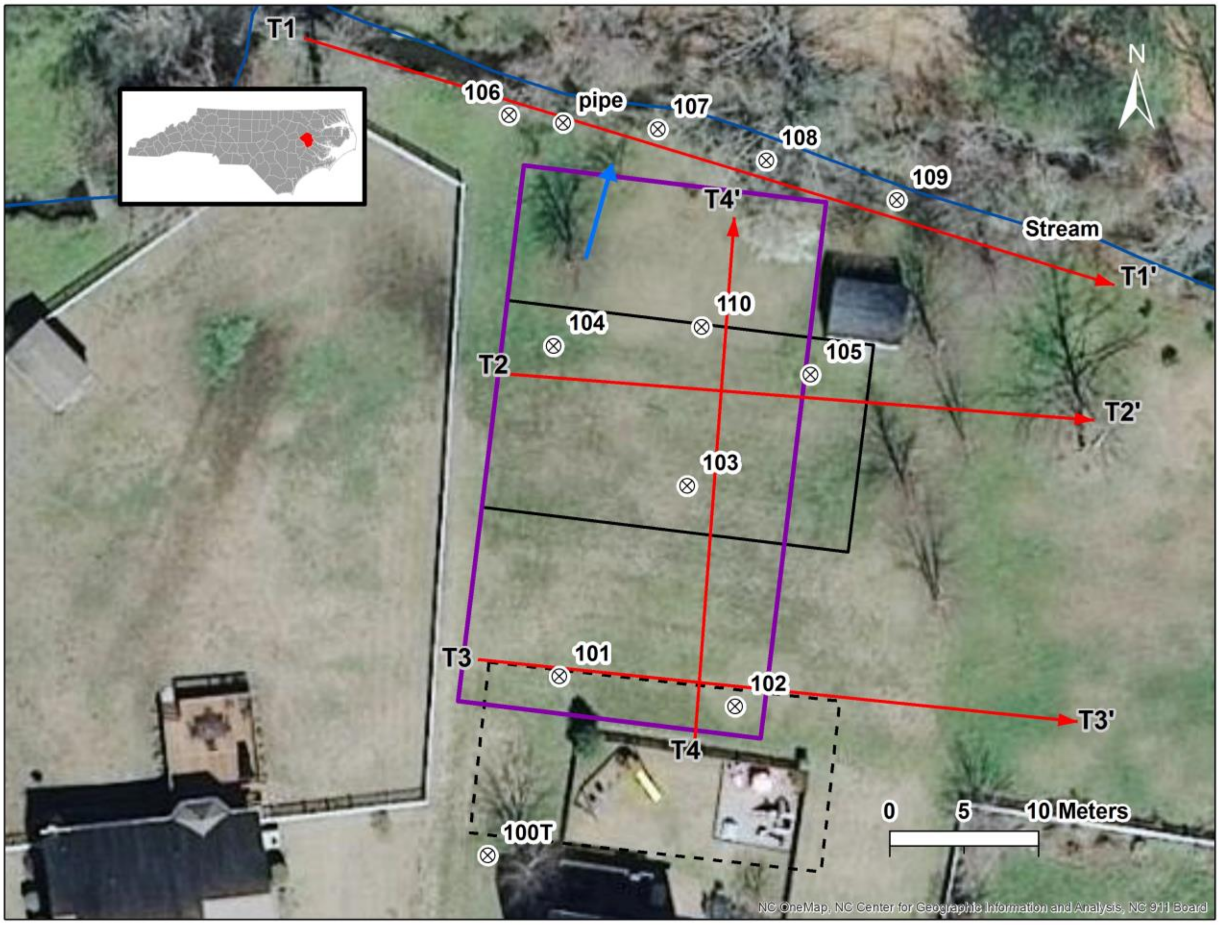
Education Center



Appendix Figure H3 shows the education center transects (solid red lines) with corresponding transect ID numbers (black and grey font), the respective location of the 1 active drainfield (black rectangle), and the general groundwater flow direction (blue arrow). The locations for cores collected were identified by a “c”.

Residential 100-400

Residential 100

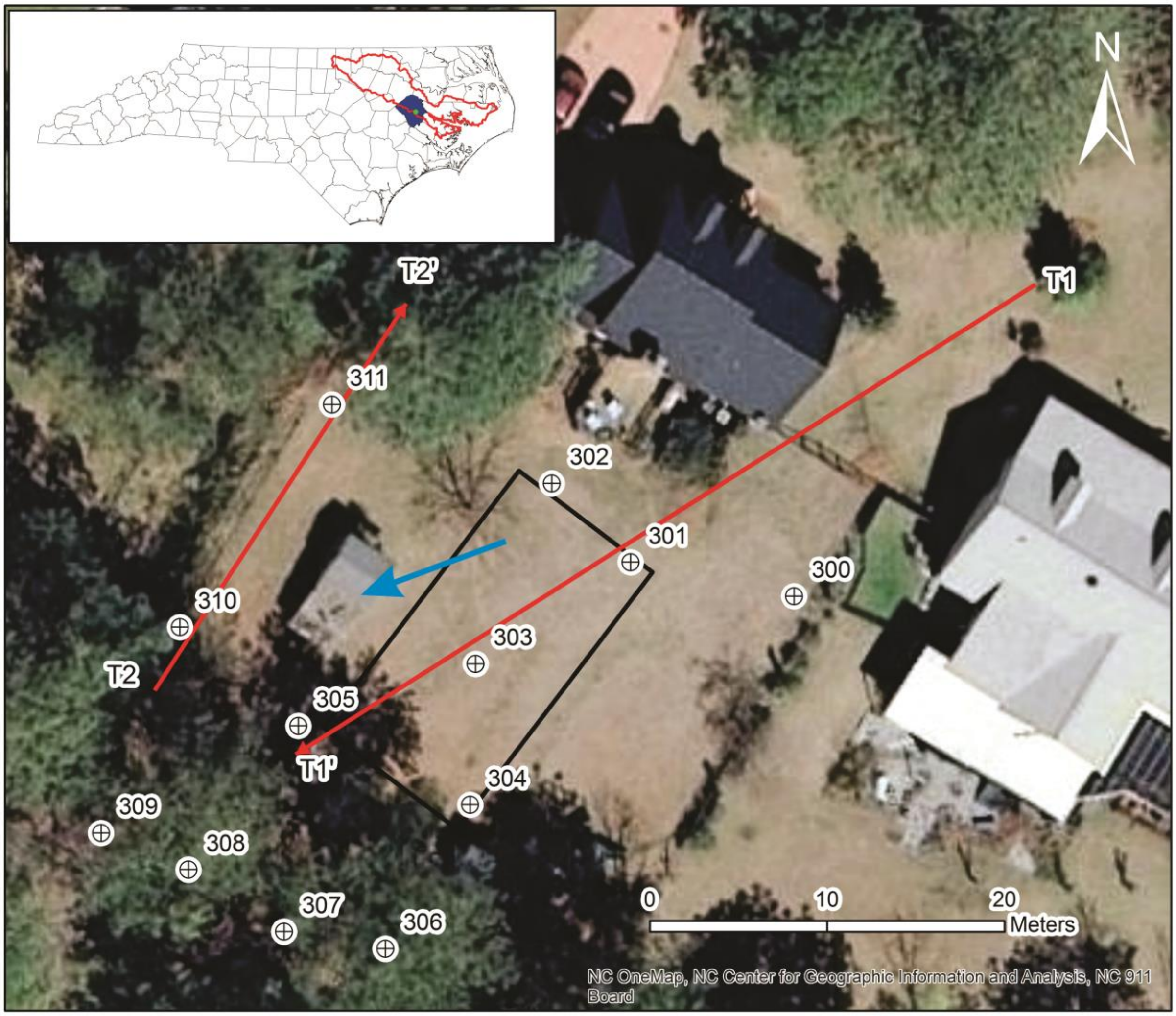


Appendix Figure H4 shows the Residential 100 transects (solid red lines) with corresponding transect ID numbers (black and grey font, T1-T4), 3D survey location (purple box), 1 active drainfield (solid black box), 1 de-activated drainfield (dashed black line). The groundwater flow direction is marked by a blue arrow.

Residential 200

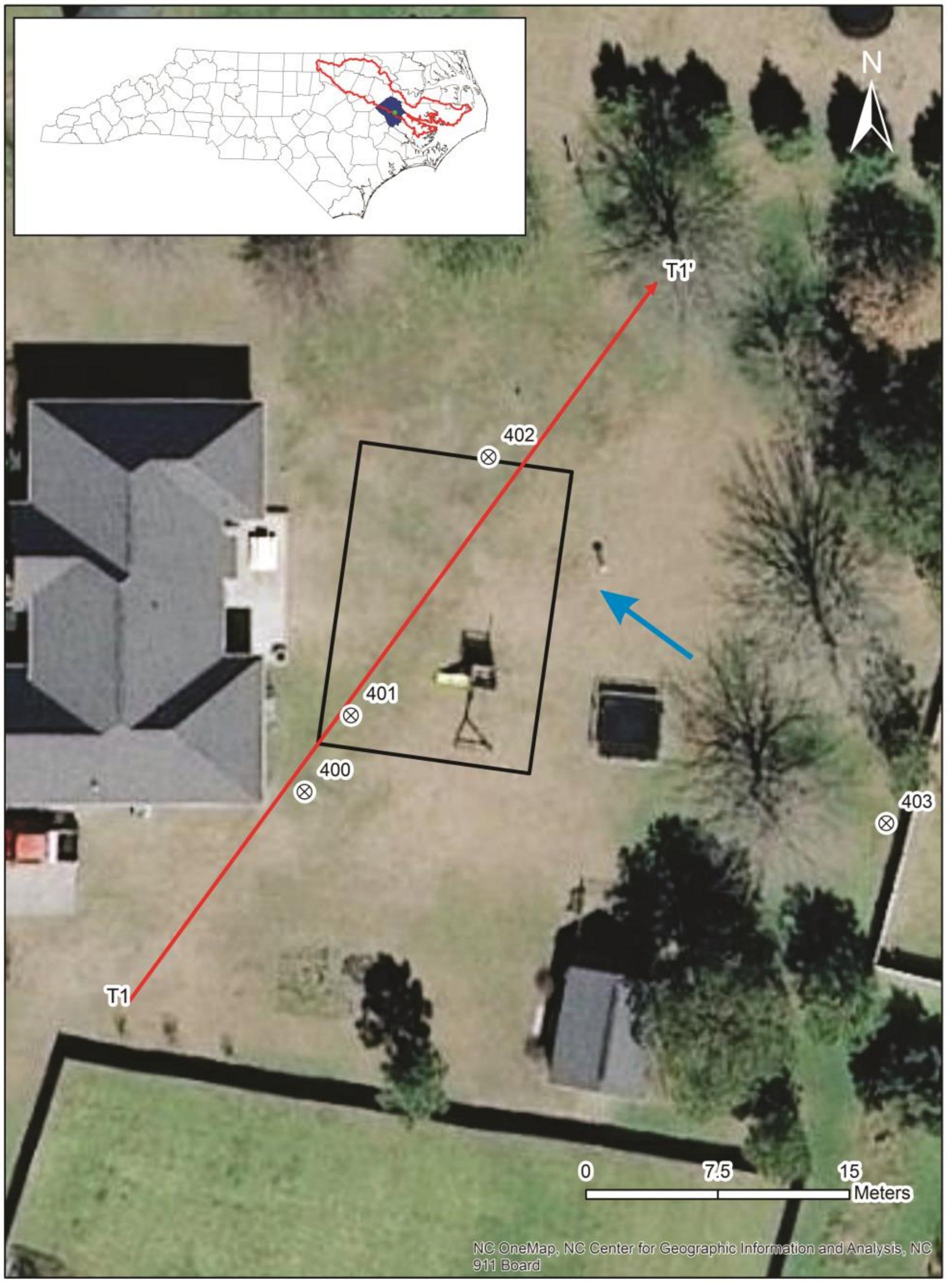
Appendix Figure H5 shows the Residential 200 transects (solid red lines) with corresponding transect ID numbers (black and grey font), and the respective location of the 1 active drainfield.

Residential 300



Appendix Figure H6 shows the Residential 300 transects (solid red lines) with corresponding transect ID numbers (black and grey font), and the respective location of the active drainfield (solid, black line rectangle).

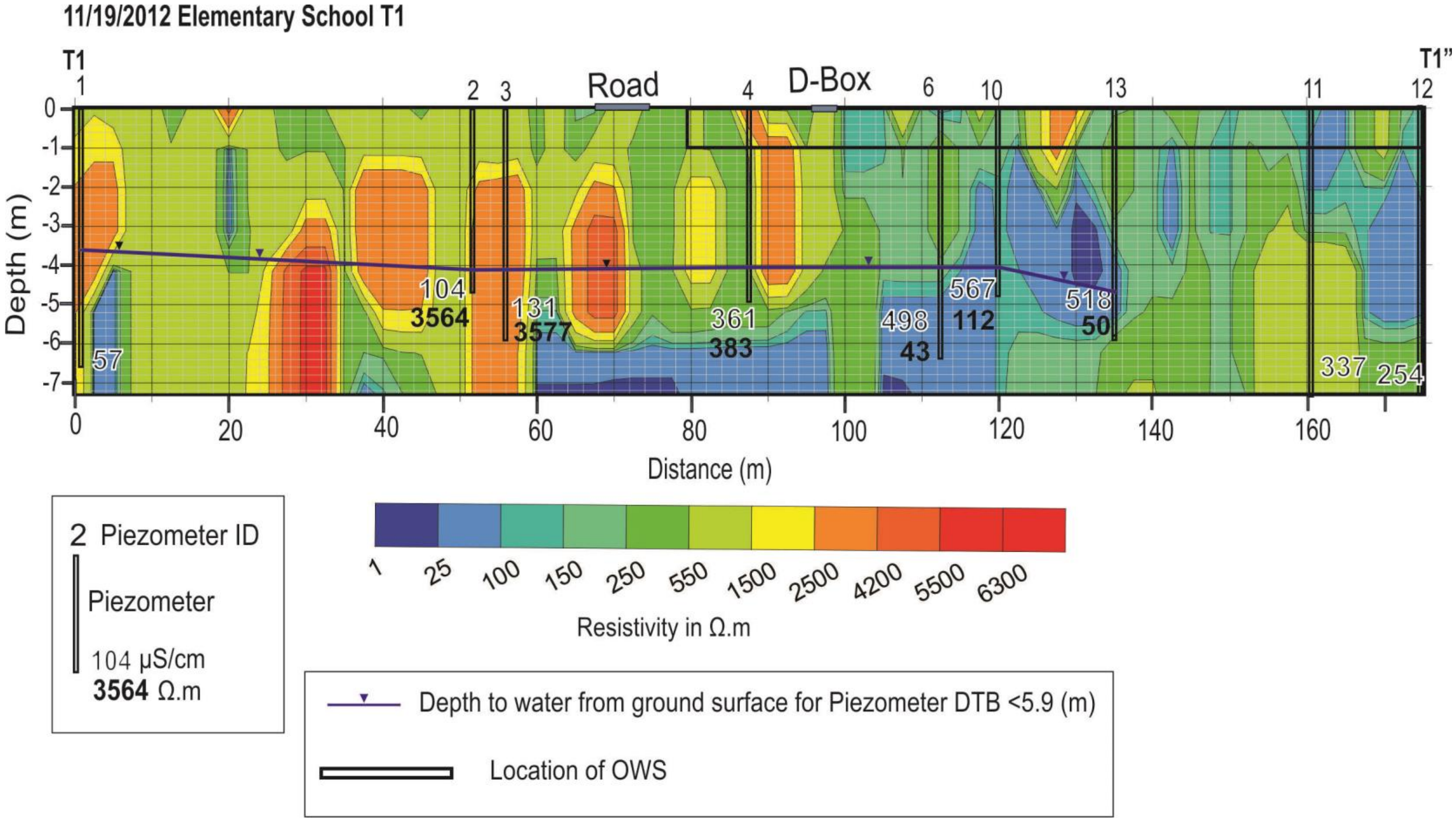
Residential 400



Appendix Figure H7 shows the Residential 400 transects (solid red lines) with corresponding transect ID numbers (black and grey font), and the respective location of the active drainfield (solid, black line rectangle).

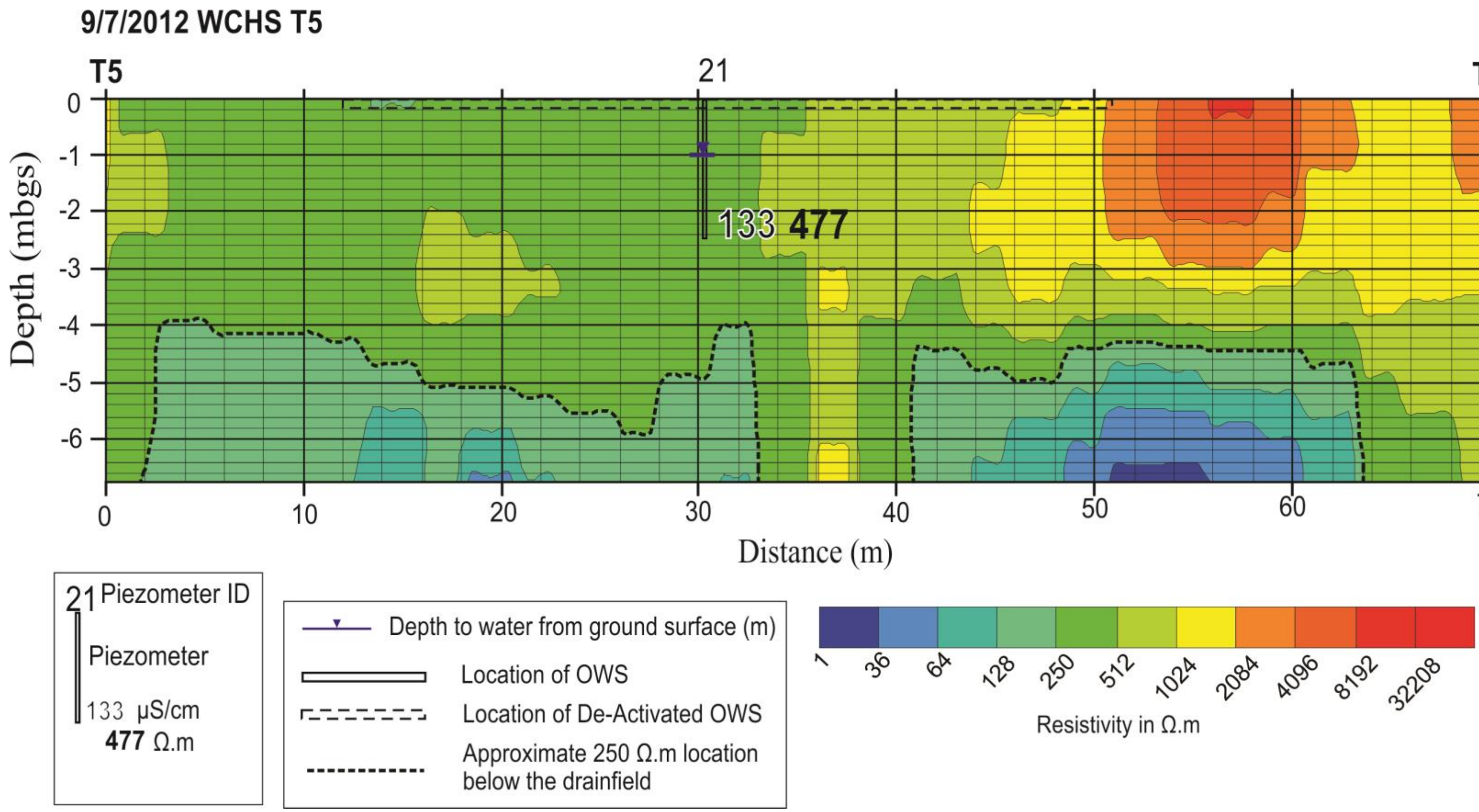
Appendix I: CCR Surveys

Elementary School



Appendix Figure I1 shows the elementary school T1 CCR survey collected on 11/19/2012. The approximate locations of the road and distribution box are marked by grey filled rectangles and labeled. The location of the drainfield is marked by a solid, black line rectangle.

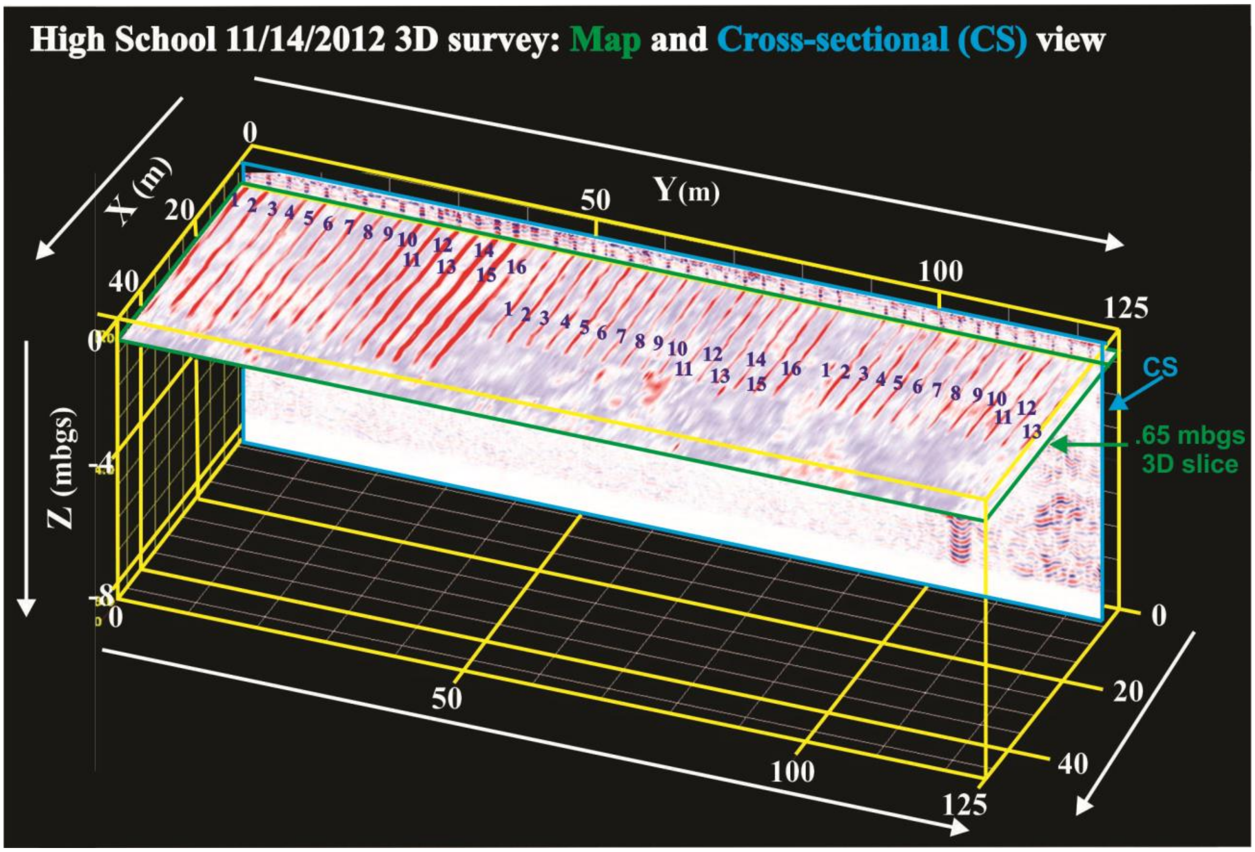
High School



Appendix Figure I2 shows the high school T5 CCR survey collected on 9/7/2012. T5 was collected perpendicular to the drainfield flow path and greater than 15m from the drainfield (Appendix Figure H1). Low resistivity zones <250 Ω.m were present below the deactivated drainfield at approximate depths of 4-6 mbgs. The transect does not show the bottom of the low resistivity areas. Future work would require the installation of piezometer screened intervals at depths assessing the low resistivity areas shown on the transect.

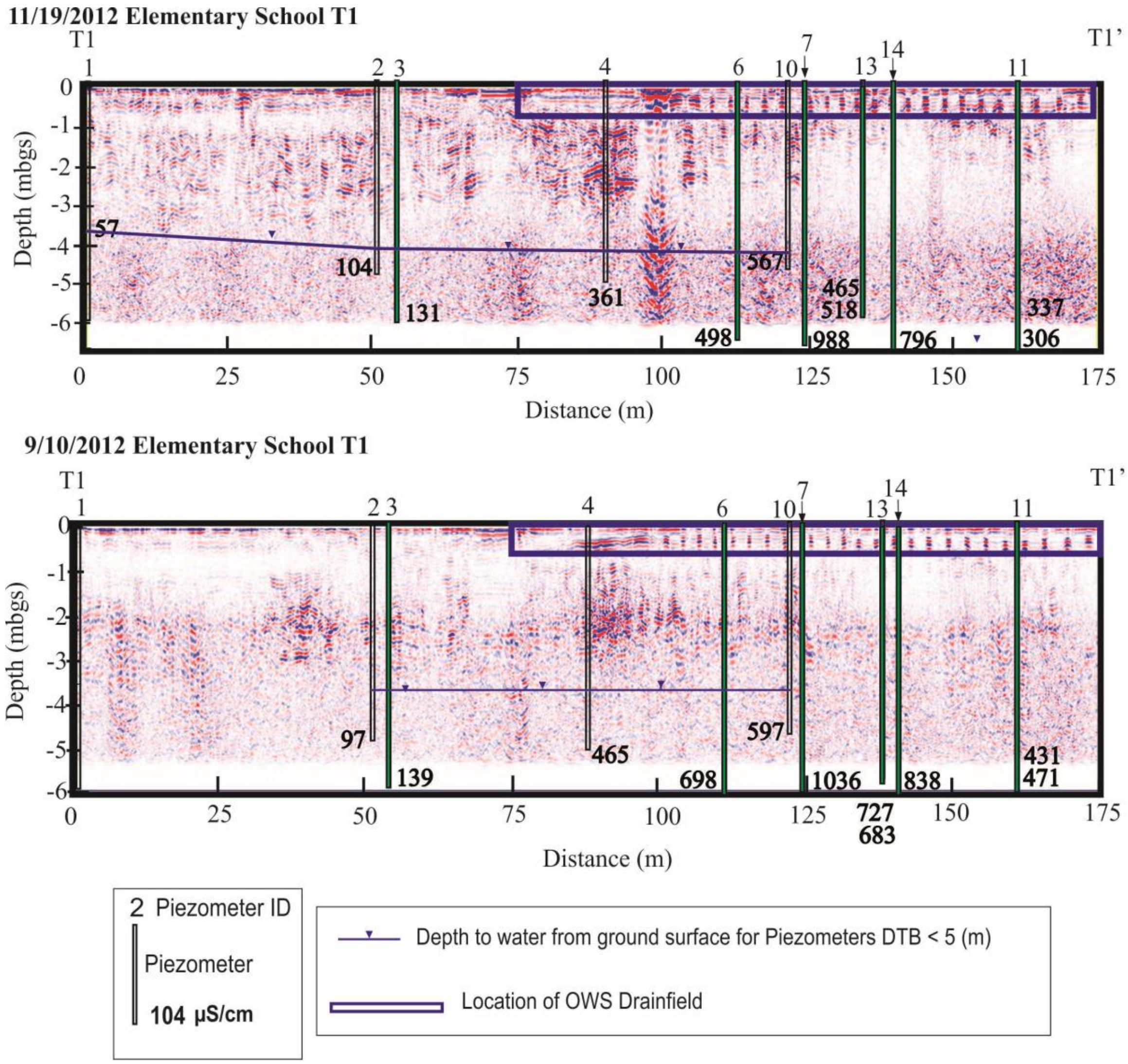
Appendix J: GPR surveys

High School



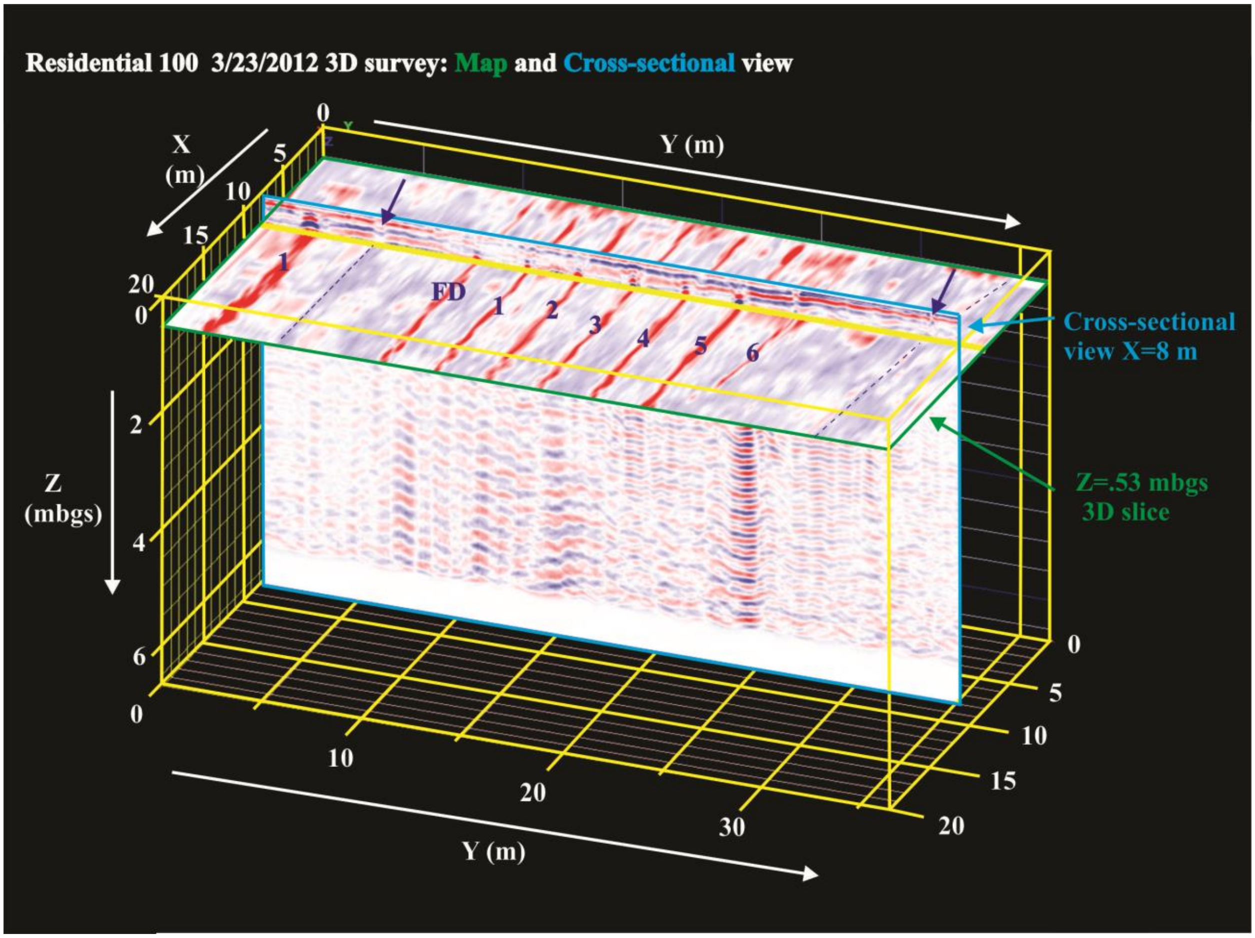
Appendix Figure J1 shows a cross section and map view of a 3D survey collected at the high school on 11/14/2012 at a depth 0.65 mbgs. The map view was used in Figure 17. The dark purple numbers mark the locations of high amplitude, positive polarity, linear reflections that correspond to the location of the high school drainfield trenches (Appendix Figure H1). The high school has 2 active OWS systems; each system has 16 active drainfield trenches (a total of 32 active drainfield trenches between the 2 systems). The high school has 1 de-activated system with 16 de-activated drainfield trenches; the 3D surveys only show 13 linear reflections. The linear reflections shown on the map view (green outlined section) can be matched with the reflections shown in the cross-sectional view (light blue outlined section).

Elementary School



Appendix Figure J2, shows T1 (Appendix Figure H2) collected on 11/19/2012 and 9/10/2012. The dark red and blue reflections present within the drainfield area are identified as the drainfield trenches.

Residential 100



Appendix Figure J3. Shows a cross-section and map view of a 3D survey collected at Residential 100 on 3/23/2012 at a depth 0.53 mbgs. The dark purple numbers mark the locations of high amplitude linear reflections that correspond to the location of the Residential 100 drainfield trenches (Appendix Figure H4). The site has 1 active system with 6 drainfield trenches (purple numbers 1-6 in the figure) and 1 de-activated system with 1 drainfield trench visible (purple number 1). The purple font "FD" marks the location of the French drain that is characterized by high amplitude, positive polarity, reflections (red linear line). The two low amplitude structures are marked by the purple dashed lines and purple arrows. In addition, the linear reflections shown in the map view (green outlined section) can be matched with the reflections in the cross-sectional view (blue outlined section).

Appendix K: Smith (2013) and the current research (CR) data

Appendix Table K1 shows the results from Mann Whitney comparisons between background and drainfield data sets collected from Smith (2013) and the current research (CR). The tables lists the site, where the data were collected from: background (BG) or drainfield (DF) areas, median values, p-values, and sample numbers for each comparison.

Site	Location	Median Groundwater Specific Conductivity (µS/cm)	Median Resistivity (Ω.m)	µS/cm p-value	Ω.m p-value	Sample Number (n)	Source
Elementary School	BG	112	997	0.0000	0.0002	20	Smith (2013)
	DF	525	104			15	Smith (2013)
High School	BG	74	857	0.0000	0.0000	20	Smith (2013)
	DF	371	52			20	Smith (2013)
Pooled Data	BG	113	466	0.0000	0.0000	36	CR
	DF	279	102			87	CR
Elementary School	BG	112	1714	0.0001	0.0001	8	CR
	DF	615	112			17	CR
High School	BG	79	1283	0.0000	0.0000	13	CR
	DF	363	81			29	CR
Education Center	BG	128	178	0.5728	0.8325	7	CR
	DF	130	161			15	CR
Residential 100	BG	198	122	0.3429	0.5362	6	CR
	DF	244	96			14	CR
Residential 300 and 400	BG	117	433	1.0000	0.2433	2	CR
	DF	107	93			6	CR

Appendix Table K2 shows the results from a regression analysis of groundwater specific conductivity and corresponding Log resistivity values. The resulting R^2 values were listed along with the sample number, site the data were collected from, and the source (the study in which the analysis was completed). The sources consisted of Smith (2013) and the current research (CR). Individual site R^2 values were not determined for Residential 300 and 400. The Log resistivity vs. groundwater specific conductivity, regression analysis, R^2 value provided a relative estimate of the sensitivity of the resistivity response to changes in groundwater specific conductivity.

Site	R^2	Sample Number (n)	Source
Elementary School	0.69	35	Smith (2013)
High School	0.75	45	Smith (2013)
Pooled Data	0.35	117	CR
Elementary School	0.60	25	CR
High School	0.72	42	CR
Education Center	0.04	30	CR
Residential 100	0.03	20	CR

Appendix L: Lithology, Soil Surveys, and Porosity

Methodology: Characterization of Lithology and Grain Size Analysis

Cores and soil samples were collected in conjunction with piezometer installation at all of the sites. Previous research by Smith (2013) collected 3 cores from the high school and 3 cores from the elementary school. The current research collected 3 cores from the education center. All cores were collected at varying depths ranging from 4.6 – 8.5 mbgs using a truck-mounted Geoprobe coring rig. Smith (2013) collected cores adjacent to CCR and GPR transects to correlate with geophysical and water quality measurements. Cores were logged and sampled at 50 cm intervals or where a distinct lithological contrast was observed (Smith, 2013). Samples were sieved at 0.5 phi intervals in a Ro-Tap sieve shaker for 15 minutes per sample to separate the sediment into grain-size fractions ranging from 0.063 – 4 mm (4 φ to – 2 φ) (Smith, 2013). Grain-size statistical analysis was carried out using GRADISTAT 4.0, according to the Folk and Ward graphical method (Blott, 2000). Grain-sizes were determined using the Wentworth grain-size scale (Smith, 2013). Previous research by Iverson (2013) at Residential 100, 200, 300, and 400 utilized the Geoprobe in conjunction with a hand auger in compact locations that the Geoprobe truck could not be utilized. Soil samples from Residential 100, 200, 300 and 400 were collected at approximate depths of 1.2 m during the boring process. The soil samples were analyzed by the North Carolina State University Soil Science Department in 2011 using the hydrometer method (Iverson, 2013). Soil samples collected at Residential 100, 200, and 400 soils were characterized as sandy clay loam (Iverson, 2013). The Residential 300 soil samples was characterized by sandy clays and sandy loams (Iverson, 2013).

Methodology: Porosity

Smith (2013) estimated median porosity values for the elementary school (41%) and the high school (43%) and found that differences in porosity values were minimal across background and drainfield locations at both sites. Researchers found that the similar porosity values across the site did not influence the differences in resistivity values between the background and drainfield locations (Smith, 20130). The log resistivity vs porosity regression analysis had $R^2 \leq 0.1$ (Smith, 2013). Smith (2013) estimated porosity using an equation by Vukovic and Soro (1992) that requires a uniformity coefficient collected from grain size analysis (d_{60}/d_{10}).

In the current study, total porosity (n) for all sites was estimated using equation L1 where b = bulk density (g/cm^3) and 2.65 (g/cm^3) is the constant for particle density (NRCS, 2015).

$$n = 100 - \left(\left(\frac{b}{2.65}\right) * 100\right) \qquad \text{(Eq. L1)}$$

Specific yield was estimated by subtracting the % water content @ 1/3 bar (33 kPa) from the % water content @ 0 bar (saturation) values obtained from NRCS water retention (NRCS, 2015). The % water content at one-third bar was the amount of soil water retained at a tension of 1/3 bar (33 kPa) and was expressed as a percentage of the whole soil on a volumetric basis (NRCS, 2015). The % water content at 0 bar (saturation) was the estimated volumetric soil water content at or near zero bar tension and was expressed as a percentage of the whole soil (NRCS, 2015). The total porosity values and specific yield values characteristic of the dominant soil types at each site are listed in Appendix Table L1 and L2.

Soil Survey Data

Appendix Table L1 Shows the soil series, soil series type, and K_{sat} found at each site in the current study. The total porosity and specific yield were calculated from soil series data (Appendix L). Additional data included the estimated location of piezometers within each soil series based on soil series maps. The soil series data were collected from NRCS (2015). The sites include: Residential 100, 200, 300, and 400 (Res-100, Res-200, Res-300, Res-400, respectively), high school (HS), elementary school (ES), and education center (EC).

Site	Soil Series ID	Soil Series Type	K_{sat} (m/day)	Total Porosity ϕ	Specific Yield (n)	Sample Number	Piezometer IDs Located within Soil Series Area	Location
Res-100	Goldsboro	Sandy Loam	0.35-1.2	0.41	20.2	16	101-102	Pitt County
Res-100	Lynchburg	Fine Sandy Loam	0.12-1.20	0.43	18.8	20	103-1105, 110	Pitt County
Res-100	Bibb	Fine Sandy Loam	1.21-3.63	0.39	22.5	3	106-109	Pitt County
Res-200	Goldsboro	Sandy Loam	0.35-1.2	0.41	20.2	16	207-213	Pitt County
Res-300	Ocilla	Loamy Fine Sand	0.35-1.2	0.37	16.3	6	300-305	Pitt County
Res-400	Ocilla	Loamy Fine Sand	0.35-1.2	0.37	16.3	6	401,402	Pitt County
Res-400	Goldsboro	Sandy Loam	0.35-1.2	0.41	20.2	16	403	Pitt County
EC	Wagram	Loamy Sand	0.35-1.2	0.37	18.8	8	1-5	Pitt County
EC	Portsmouth	Loam	0.35-1.2	0.43	20.5	14	6-13	Pitt County
ES	Autryville	Loamy Fine Sand	0.35-1.2	0.37	21.2	5	16-20	Craven County
ES	Suffolk	Loamy Sand	0.35-1.21	0.42	22.2	3	1-15	Craven County
HS	Conetoe	Loamy Sand	0.35-3.63	0.41	23.4	5	3-22,24	Craven County
HS	Arapahoe	Fine Sandy Loam	1.21-3.63	0.4	20.3	8	1,2	Craven County
HS	Masontown and Muckalee	Mucky Fine Sandy Loam and Sandy Loam	1.21-3.63	0.46	22.7	5	23	Craven County

Appendix Table L2 shows the total porosity for each site. The total porosity for each site was calculated by averaging the calculated total porosities for each soil series found at each site. Specific yield was also calculated in this manner. The ranges of both total porosity and specific yield are provided. Residential 100 had the lowest specific yield range. The F (formation factor) was calculated for each site using the total porosity and specific yield values in this chart.

Site	Total Porosity φ	Total Porosity φ Range	Specific Yield (n)	Specific Yield (S_y) Range	Sample Number	F
Residential 100	0.41	.34-.47	19.6	8-26	39	3.09
Residential 200	0.41	.35-.47	20.2	15-24	16	3.19
Residential 300	0.38	.36-.40	16.3	11-22	6	3.52
Residential 400	0.4	.35-.47	19.1	11-24	22	3.29
Education Center	0.41	.34-.47	19.9	11-27	22	3.19
Elementary School	0.39	.35-.45	21.6	19-24	8	3.4
High School	0.43	.39-.55	31.8	17-28	18	3.09
Pooled Data	0.40	.34-.55	21.21	8-28	131.00	3.25

Appendix M: Hydraulic Conductivity (K_{sat})

Appendix M: Smith (2013) and Iverson (2013) Hydraulic Conductivity Methodology

Iverson, (2013) used K_{sat} data taken from the National Cooperative Soil Survey (1971) and the Bouwer and Rice Slug-test Method (1976) to estimate hydraulic conductivity for Residential 100-400. The National Cooperative Soil Survey (1971) estimated K_{sat} values using permeability data collected from the USDA Pitt County Soil Survey (1974) that utilized constant head permeameter tests for the dominant soils at Residential 100-400. The average K determined by Iverson (2013) at Residential 100 was 0.3 m/d.

Smith (2013) estimated K values at the high school and elementary school using 3 different methods: the Hazen Method, Bouwer and Rice Slug-test Method (1976) and a Craven County Soil Survey (USDA, 1989). K_{sat} values that were obtained from the Craven County Soil Survey (USDA, 1989), were estimated using a constant head parameter method to calculate the permeability for the dominant soil types at the schools. Smith (2013) compared Log resistivity values collected from the CCR surveys to corresponding estimated K values calculated from the Bower and Rice Slug Test Method at the schools. The regression analysis between the Log resistivity values and K estimates had a R^2 value less than 0.1 (Smith, 2013). The results showed a weak relationship between the resistivity and K and indicated K did not influence the significant changes in resistivity across background and drainfield locations (Smith, 2013).

The current study, K_{sat} values collected from NRCS (2015) were listed in Appendix Table L1; the methodology for these values were listed in the Methods section.

Appendix N: Current Research and Humphrey et al. 2013 WRRI Report Nutrient Data.

Previous studies have characterized elevated concentrations of TDN, PO_4 and Cl found below OWS drainfields and with distance from OWS drainfields as part of an OWS drainfield plume (Harman 1996, Corbett 2002). The Humphrey et al. (2013) report assessed NO_3+NO_2, DKN, Cl, and PO_4 values collected from laboratory analysis at the ECU CERL. All of the nutrient data used in the report were collected and analyzed during the current study (Appendix D). Total dissolved nitrogen (TDN) was calculated by adding NO_3+NO_2 and DKN values (Humphrey et al. 2013). The methods for data collection and laboratory analyses were discussed in the Methods section of the current study and in the Humphrey et al. (2013). The report's objective was to assess the spatial variability of TDN, PO_4, Cl, and NH_4 values across background, drainfield and downgradient piezometers as well as from the tank/distribution box and from surface water bodies (if present) (Humphrey et al. 2013).

The current study calculated TDN, PO_4 and NH_4 mean values for tank, background, drainfield, downgradient, ≤ 15 m downgradient, surface water, and spring locations (Appendix Table N1). The ≤ 15 m downgradient data set was collected to characterize the nutrients downgradient of the drainfield. In North Carolina, 15 m was the minimum offset distance between surface water bodies and OWS with design flows of 11,340 liters/day or lower (Section. 1900, 2007). The concentrations of the nutrient parameters collected less than 15 m downgradient of the drainfield were expected to be similar to the drainfield concentrations. The TDN, PO_4, NH_4, and Cl values used in the current study were listed in Appendix D.

Appendix Table N1 shows mean values for TDN, Cl, PO_4, and NH4 collected from the Tank (or Distribution box) and piezometers located in drainfield (DF), downgradient (DG), downgradient areas ≤15m, RP (riparian buffer), spring, surface water bodies (SW), and background (BG) areas. Sample number is n. All DG values collected from Residential 100 were located ≤ 15m downgradient of the drainfield. The RP, Spring, and SW were located > 15 m downgradient of the drainfield at all sites. The boxplots for TDN and Cl values are shown in Appendix Figures N1-4.

Site	Parameter (mg/L)	Location Data were Collected From							
		Tank	DF	DG	DG ≤15m	RP	Spring (DG)	SW (DG)	BG
High School	TDN	80.83	22.11	2.44	4.1	-	-	0.85	0.82
	Cl	106.57	25.82	5.46	9	-	-	5.64	10.51
	PO_4	8.86	0.06	0.14	0.27	-	-	0.008	0.04
	NH_4	76.3	0.33	0.26	0.3	-	-	0.09	1.09
	n	3	36	31	16	-	-	1	25
Elementary School	TDN	28.3	23.19	2.54	3	2.39	10.78	3.74	1.15
	Cl	60.89	52.19	24.75	38.86	20.99	33.25	13.99	3.69
	PO_4	5.14	0.32	0.17	0.55	0.07	0.22	0.1	0.09
	NH_4	24.87	0.18	0.43	0.19	0.47	0.21	0.24	0.26
	n	3	31	19	4	15	4	6	11
Education Center	TDN	65.35	4.45	3.97	4.7	-	-	-	1.83
	Cl	81.45	10.84	12.14	8.89	-	-	-	10.01
	PO_4	5.99	0.38	0.16	1.08	-	-	-	0.92
	NH_4	65.31	1.09	0.61	0.97	-	-	-	0.12
	n	3	9	38	6	-	-	-	6
Residential 100	TDN	49.33	8.86	6.99	-	-	-	2.99	4.5
	Cl	62.84	17.08	14.91	-	-	-	17.76	9.75
	PO_4	5.77	0.12	0.19	-	-	-	0.06	0.18
	NH_4	45.52	7.01	0.8	-	-	-	1.34	0.45
	n	3	15	20	-	-	-	5	7

TDN and PO_4 values were collected from the tank/distribution box, drainfield and downgradient piezometers to determine the treatment efficiency with distance from the tank. The tank TDN and PO_4 values were expected to be highest in the tank and drainfield (Appendix Table F1). Humphrey et al. 2013 calculated the treatment efficiency of nutrient values: TDN and PO_4 from the tank to the drainfield piezometers and from the tank to downgradient piezometers using equation N1 (Eq. N1).

$$TE = \frac{\text{Tank}-\text{X}}{\text{Tank}} * 100 \qquad \text{Eq. N1}$$

TE is the treatment efficiency (in percent); Tank represents the TDN, PO_4 or NH_4 mean values collected from the tank; X represents corresponding TDN, PO_4, NH_4 mean nutrient values collected from background, downgradient, ≤15m downgradient, surface water and spring locations. The nutrient values: TDN, PO_4, NH_4, were given in mg/L. The treatment efficiencies for TDN, PO_4, and NH_4 from the tank to drainfield, tank to downgradient piezometers, tank to piezometer located ≤15m from the drainfield, tank to surface water bodies and tank to spring were calculated. Research by Humphrey et al. calculated the treatment efficiency for TDN, PO_4 and NH_4 values from the tank to the drainfield plume core; the drainfield plume core was defined as the area below the drainfield with the highest TDN concentration.

The treatment efficiency from the tank to the drainfield for TDN values was highest at the education center, followed by Residential 100 then the high school and the elementary school (Appendix Table N2). The TDN treatment efficiency calculated at the education center indicated that a significant reduction in the TDN concentration occurred from the tank to the drainfield and downgradient piezometers. It was important to remember that the wastewater inputs at the education center were expected to be low relative to the other sites in the current study (Appendix Figure N2-4). The treatment efficiency values for PO_4 and NH_4 at all sites had significant reductions in concentration greater than 90% from the tank to drainfield piezometers (Appendix Figure N2). Wastewater inputs were expected to be highest in the high school and elementary school drainfield. The high school and elementary school had the 2 lowest TDN reductions from the tank to the drainfield,

Appendix Table N2 shows TDN, PO_4, and NH_4 treatment efficiencies calculated from the tank to the drainfield. The sample number is the combined tank and DF samples used (Appendix Table N1). Italics identify the lowest nutrient reduction values on the Table.

Site	Nutrient Tank to DF Treatment Efficiency Calculations			
	TDN % Reductions	PO_4 % Reductions	NH_4 % Reductions	Tank to DF Sample Number
High School	*73*	99	100	39
Elementary School	*18*	94	94	34
Education Center	93	94	94	12
Residential 100	*82*	98	98	18

The treatment efficiencies from tank to downgradient piezometers were calculated for all 4 sites (Appendix Table N3). The parameters: TDN, PO_4 and NH_4 treatment efficiency for all sites exceeded 90% reduction from the tank to downgradient piezometers, except at Residential 100 where only an 86% reduction in TDN values from the tank to the downgradient piezometers was present (Appendix Table N3).

Appendix Table N3 shows TDN, PO_4, and NH_4 treatment efficiencies calculated from the tank to the downgradient piezometers and from the tank to the RP (riparian buffer). The sample number is the combined tank and DG samples used (Appendix Table N1). Italics identify the lowest nutrient reduction values on the Table.

Site	Nutrient Tank to DG Treatment Efficiency Calculations			
	TDN % Reductions	PO_4 % Reductions	NH_4 % Reductions	Tank and DG Sample Number
High School	97	98	100	34
Elementary School	91	97	98	22

Education Center	94	97	97	41
Residential 100	*86*	97	97	23
Elementary School: RP	92	99	98	15

The TDN, PO_4, and NH_4 values collected less than 15 m from the drainfield were also assessed independently of the pooled downgradient values at each site. Treatment efficiencies were calculated for TDN, PO_4, and NH_4 parameters collected from the tank and piezometers ≤15 m downgradient of the drainfield (Appendix Table N4). TDN reductions were highest at the high school followed by the education center, the elementary school, and Residential 100 (Appendix Table N4). PO_4 reductions were highest at the high school and Residential 100 followed by the education center and the elementary school (Appendix Table N4). NH_4 reductions were highest at the high school, then the education center, elementary school and Residential 100 (Appendix Table N4). All of the Residential 100 downgradient values were collected less than 15 m downgradient of the drainfield. The values for Residential 100 were listed in Appendix Table N3 column "DG".

Appendix Table N4 shows TDN, PO_4, and NH_4 treatment efficiencies calculated from the tank to the piezometers located ≤15m downgradient piezometers. The sample number is the combined tank and ≤15m DG samples used (Appendix Table N1). Italics identify the lowest nutrient reduction values on the Table.

Site	**Nutrient Tank to DG ≤15m from the DF Treatment Efficiency Calculations**			
	TDN % Reductions	**PO_4 % Reductions**	**NH_4 % Reductions**	**Tank and ≤15m DG Sample Number**
High School	95	97	100	16
Elementary School	*89*	*89*	98	4
Education Center	93	*82*	99	6
Residential 100	*86*	97	97	23

The TDN, PO_4 and NH_4 reductions from the tank to piezometers ≤15 m downgradient of the drainfield were highest at the high school. The treatment efficiency results for TDN reduction from the tank to the high school piezometer 25d was 71%, and the average TDN value was 16.6 ± 8.2 mg/L. The high school piezometer 25d was located approximately 9 m downgradient from the drainfield within the OWS wastewater plume.

Treatment efficiencies were also calculated from the tank to piezometers located greater than 15 m from drainfield at the elementary school (n=15) and the high school (n=15). The TDN, PO_4, and NH_4 treatment efficiency reduction results were all greater than 98%, except for the elementary school TDN treatment efficiency (91%). The groundwater specific conductivity values collected from downgradient piezometers were highest at piezometer 25d and 22d (Figure 17). Piezometer 22d was located approximately 88 m downgradient from the drainfield. The high school piezometer 22d the treatment efficiency reduction from the tank to the piezometer was greater than 98% for all 3 nutrients (TDN, PO_4, and NH_4).

The treatment efficiency from the tank to surface water bodies was assessed for TDN PO_4, and NH_4 at the schools and Residential 100 (Appendix Table N5). The education center did not have a nearby surface water body that was included in sampling during the current study. The Residential 100: SW consisted of a stream and pipe. The Residential 100 pipe discharged into the stream, and both were located approximately 20 m from the drainfield (Appendices Figure B6 and Figure H4). The Elementary School: SW was a stream located ≥30 m from the drainfield, and the Elementary School: Spring was located approximately 25 m from the drainfield (Appendix Figure H2). The elementary school distance from the stream to the drainfield was measured by Smith (2013). The High School: SW was located greater than 160 m downgradient from the drainfield (Appendix Figure H1).

Appendix Table N5 shows TDN, PO_4, and NH_4 treatment efficiencies calculated from the tank to surface water bodies. Italics identify the lowest nutrient reduction values on the Table.

Site and DG Location	Nutrient Tank to SW Treatment Efficiency Calculations			
	TDN % Reductions	PO_4 % Reductions	NH_4 % Reductions	Tank to SW Sample Number
High School: SW	99	100	100	1
Elementary School: Spring	*62*	96	99	4
Elementary School: SW	*87*	98	99	6
Residential 100: SW	94	99	97	5

The TDN, PO_4 and NH_4 reductions were highest at the high school (Appendix Table N5). The high school surface water body was located $\geq$ 50 m downgradient of the drainfield. The second highest TDN reduction was at Residential 100: SW followed by Elementary School: SW and then the Elementary School: Spring. The second highest PO_4 reductions occurred at Residential 100: SW, followed by Elementary School: SW and then the Elementary School: Spring. All PO_4 and NH_4 reductions from the tank to surface water bodies or springs were greater than 90%. The second highest NH_4 reduction occurred at both Elementary School: SW and Elementary School: Spring followed by the Residential 100: SW (Appendix Table N5).

Nutrient to chloride ratios were used to determine if reduction processes were present. Chloride can move more freely through the subsurface compared to NO_3, PO_4, and NH_4, which were susceptible to reduction via transformation to a gaseous phase: NO_3 can be reduced via nitrification, NH_4 can be reduced via anammox and PO_4 can be reduced via absorption or mineral precipitation. The nutrient to chloride ratios were listed in Appendix Table N6. The nutrient to chloride ratios were calculated using mean values from Appendix Table N1.

Appendix Table N6 shows the nutrient to chloride ratios for the values collected from locations in the Tank, DF (drainfield), DG (downgradient), DG ≤15m (less than 15m downgradient of the drainfield), SW (surface water bodies), RB (riparian buffer) and a Spring.

Site	Location where data were collected from					
	Tank			DF		
	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio
High School	0.76	0.083	0.083	0.86	0.002	0.013
Elementary School	0.46	0.084	0.408	0.44	0.006	0.003
Education Center	0.80	0.074	0.802	0.41	0.035	0.101
Residential 100	0.79	0.092	0.724	0.52	0.007	0.410

Site	Location where data were collected from					
	DG			DG ≤15m		
	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio
High School	0.45	0.026	0.048	0.456	0.030	0.033
Elementary School	0.10	0.007	0.017	0.077	0.014	0.005
Education Center	0.33	0.013	0.050	0.469	0.013	0.054
Residential 100	0.47	0.013	0.054	0.17	0.003	0.075

Site	Location where data were collected from			
	SW and Spring			
	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio	Sample Number
High School: SW	0.15	0.001	0.016	1
Elementary School: Spring	0.32	0.007	0.006	4
Residential 100	0.17	0.003	0.075	5

Site	Location where data were collected from			
	RP			
	TDN/Cl Ratio	PO_4/Cl Ratio	NH_4/Cl Ratio	Sample Number
Elementary School: RB	0.11	0.003	0.022	15

Treatment efficiencies were calculated using Cl ratios for mean NO_3, PO_4, and NH_4 listed in Appendix Table N1. The nutrient to chloride ratios were provided in Appendix Figure N6 and the treatment efficiency values for the nutrient to Cl ratios were listed in Appendix Table N7. The negative nutrient to chloride ratios indicate that the nutrient increased relative to chloride compared to the tank values (Appendix Table N7).

Appendix Table N7 shows Treatment Efficiency (TE) values calculated for TDN to Chloride, PO4 to Chloride, and NH4 to Chloride values. The TE values were calculated to estimate reductions in nutrients with respect the chloride concentration from the tank to drainfield, tank to downgradient piezometers, tank to downgradient piezometers located ≤15m from the drainfield, and tank to SW (surface water bodies), RB (riparian buffer) and a Spring.

Site	TE: Tank to Drainfield (%)		
	TDN/Cl TE	PO_4/Cl TE	NH_4/Cl TE
High School	*-13*	97	85
Elementary School	*4*	93	99
Education Center	*49*	*52*	87
Residential 100	*34*	92	*43*

Site	TE: Tank to DG (%)			TE: Tank to DG ≤15m (%)		
	TDN/Cl TE	PO_4/Cl TE	NH_4/Cl TE	TDN/Cl TE	PO_4/Cl TE	NH_4/Cl TE
High School	*41*	*69*	*43*	*40*	*64*	*60*
Elementary School	*78*	92	96	83	83	99
Education Center	*59*	82	94	*42*	83	93
Residential 100	*40*	86	93	*68*	*52*	82

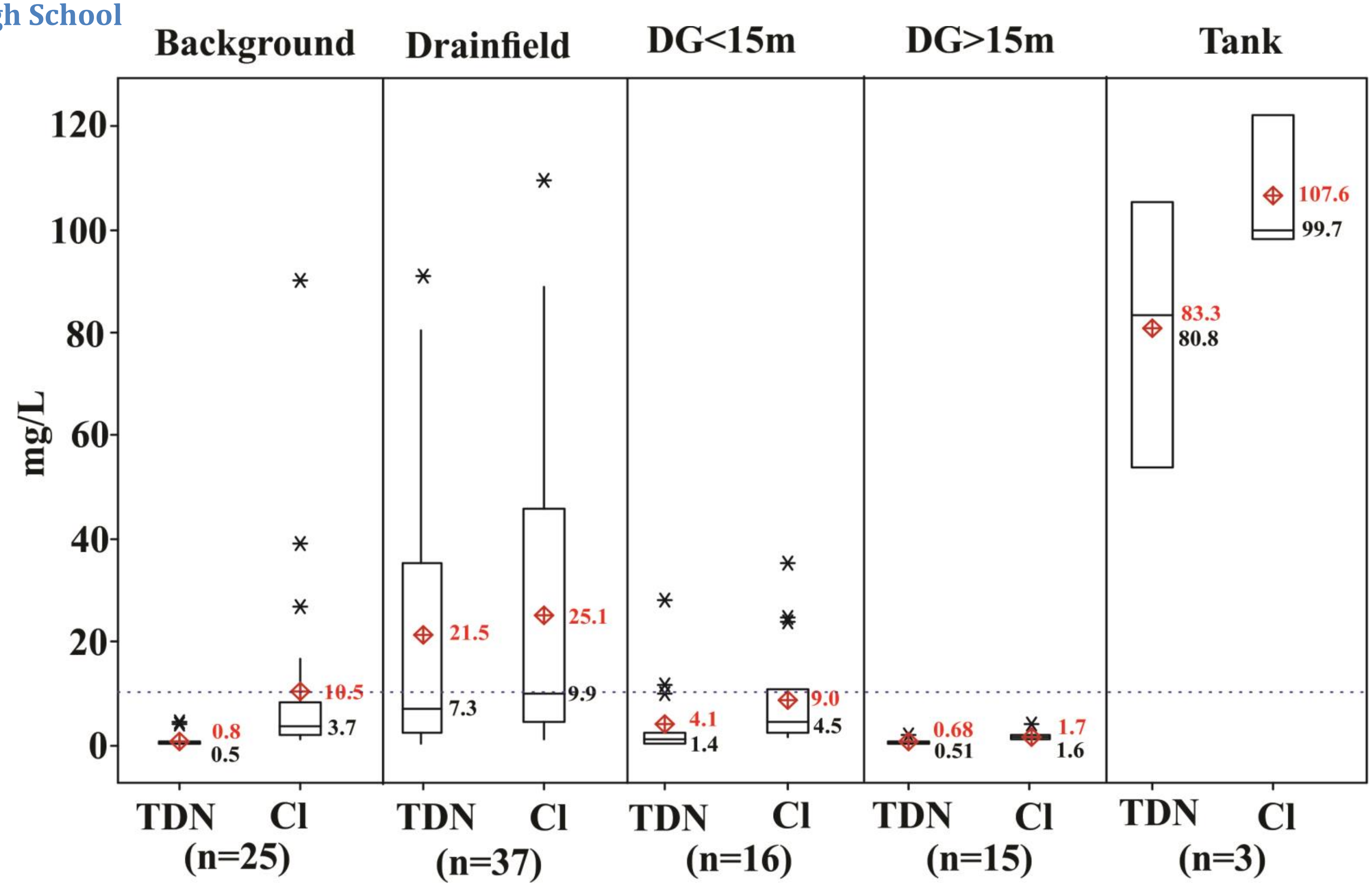
Site	TE: Tank to RP (%)		
	TDN/Cl TE	PO_4/Cl TE	NH_4/Cl TE
Elementary School: RB	*76*	96	95

Site	TE: Tank to SW and Spring (%)		
	TDN/Cl TE	PO_4/Cl TE	NH_4/Cl TE
High School	80	98	81
Elementary School: Spring	*30*	92	98
Elementary School: SW	*68*	98	96
Education Center	-	-	-
Residential 100	*79*	96	90

The treatment efficiencies for TDN to chloride ratios from the tank to the drainfield were highest at the education center followed by Residential 100, then the elementary school and were the lowest at the high school, where no reductions were present (Appendix Table N7, top table). The schools had minimal to no TDN reductions from the tank to the drainfield (Appendix Table N7). Comparatively the treatment efficiency reductions of the PO_4 to chloride ratio from the tank to drainfield was highest at the high school followed by the elementary school, then Residential 100 then the education center (Appendix Table N7, top table). The reductions calculated for the NH_4 to chloride ratio from the tank to the drainfield was highest at the elementary school followed by the education center, the high school, and Residential 100 (Appendix Table N7, top table).

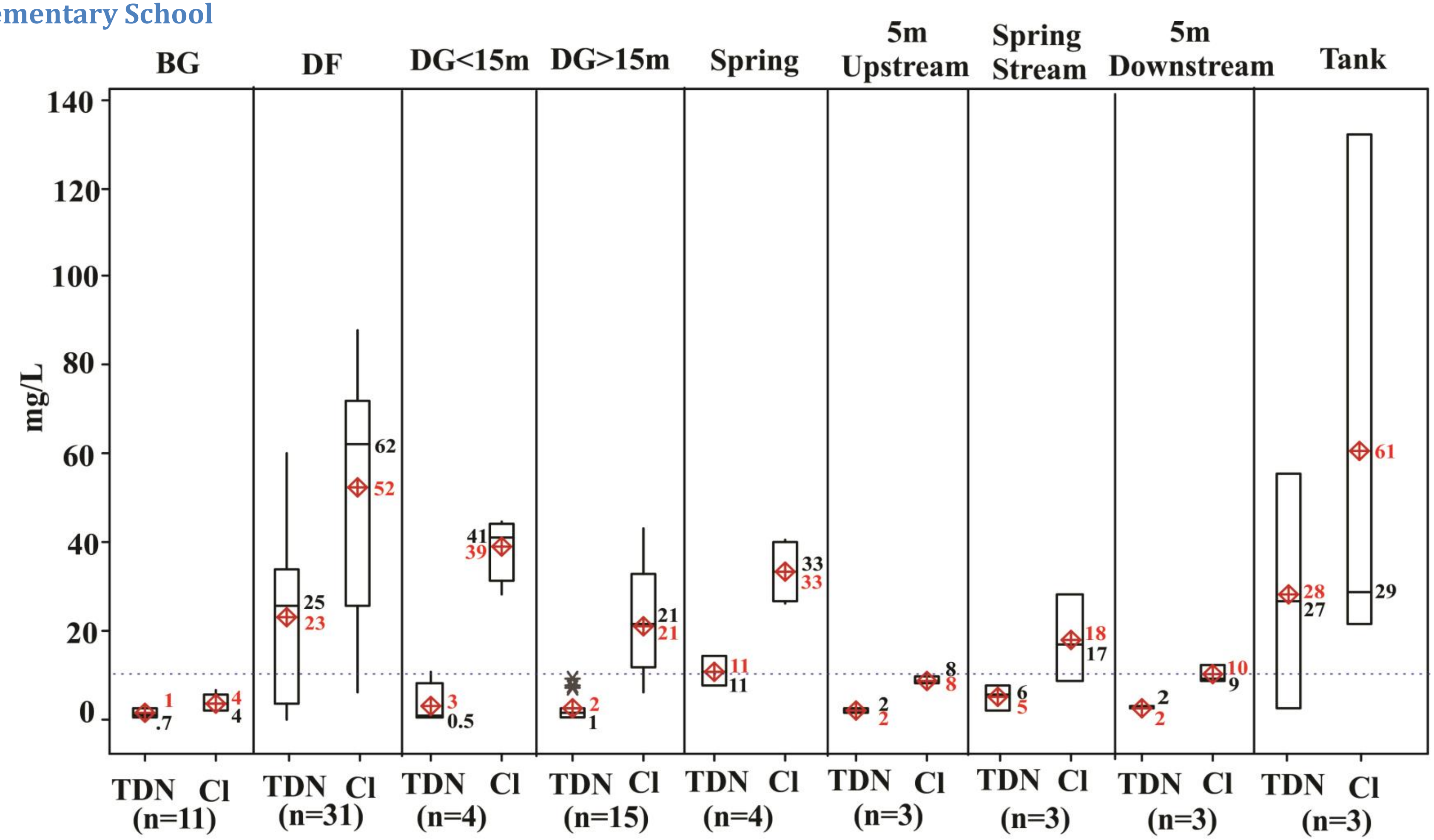
Across all sites and the majority of locations (BG, DF, DG, etc.) TDN values showed the most variability in treatment efficiency. Additional boxplots of TDN and chloride data sets for each site were used to show the spatial dataset distribution and median values (Appendix Figure N1-4). The additional focus on the TDN dataset is due to the potentially high nitrate concentrations characteristic of wastewater inputs. The US EPA regulates nitrate found in drinking water, and the standards for drinking water require the nitrate present to be less than 10 mg/L (US EPA, 2002). The regulated standards were emplaced due to the adverse health effects elevated nitrate levels in drinking water can have on people especially infants and expectant mothers (Baird, 1997). Appendix Figures N1-4 have a reference line set at 10mg/L to show when the EPA standards for nitrate in drinking water may be exceeded by the samples processed at the CERL. Humphrey et al. (2013) utilized boxplots to show and characterize site specific spatial variably in TDN and PO_4 values collected from background, drainfield and downgradient piezometers, the tank/distribution box, and nearby surface water bodies (if present). The current study incorporated TDN data sets selected from different locations and with additional data. The current study also incorporated Cl data sets to aid in visualization changes in TDN with distance from the drainfield.

High School



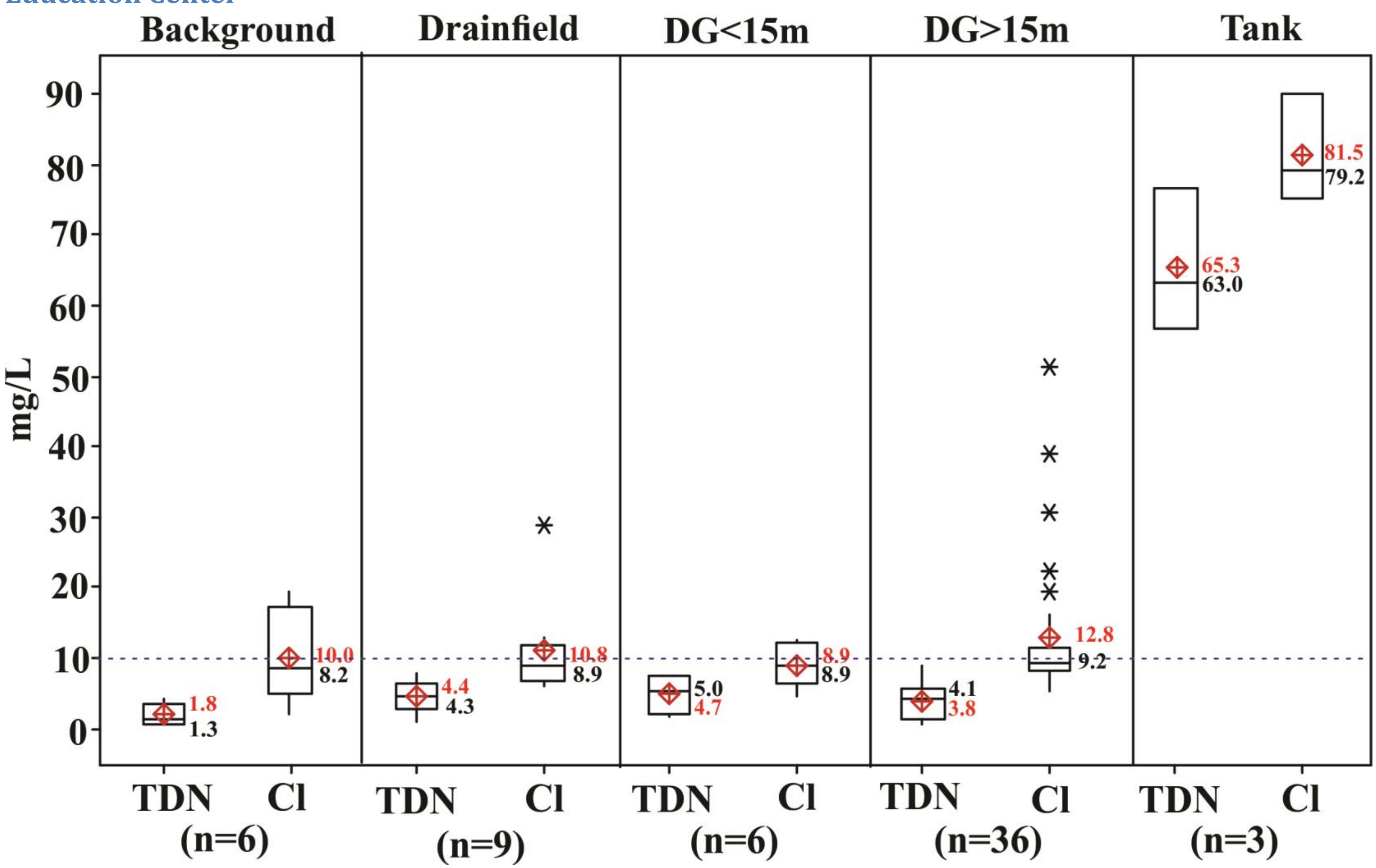
Appendix N Figure 1. Shows Boxplots of TDN and Cl in mg/L collected at the high school from background (BG), drainfield (DF), areas less than 15m downgradient of the OWS drainfield and areas greater than 15m downgradient of the OWS drainfield and tank values. On each box plot the median values are listed in black, bold fond beside the median line and the mean values are marked by the red diamond on each box plot and the red bold font. The sample numbers (n) are listed below the TDN and Cl markers. The purple dashed line marks the mg/L requirement for drinking water.

Elementary School



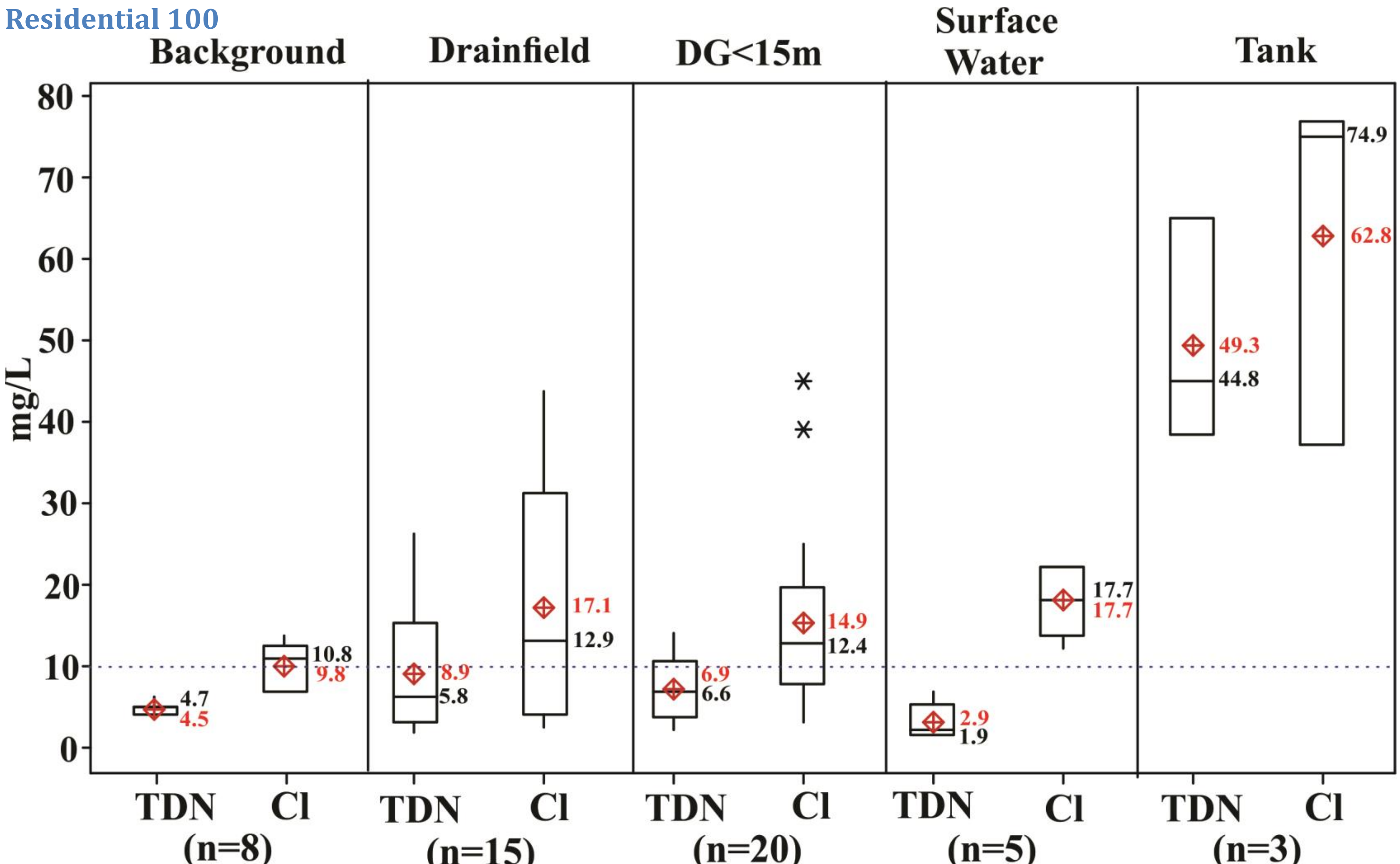
Appendix N Figure 2. Shows Boxplots of TDN and Cl in mg/L collected at the elementary school from background and drainfield areas, areas less than 15m downgradient of the OWS drainfield, areas greater than 15m downgradient of the OWS drainfield, and from surface water bodies: Spring 1, 5m upstream, 5m downstream and from the tank. On each box plot the median values are listed in black, bold fond beside the median line and the mean values are marked by the red diamond on each box plot and the red bold font. The sample numbers (n) are listed below the TDN and Cl markers. The purple dashed line marks the mg/L requirement for drinking water.

Education Center



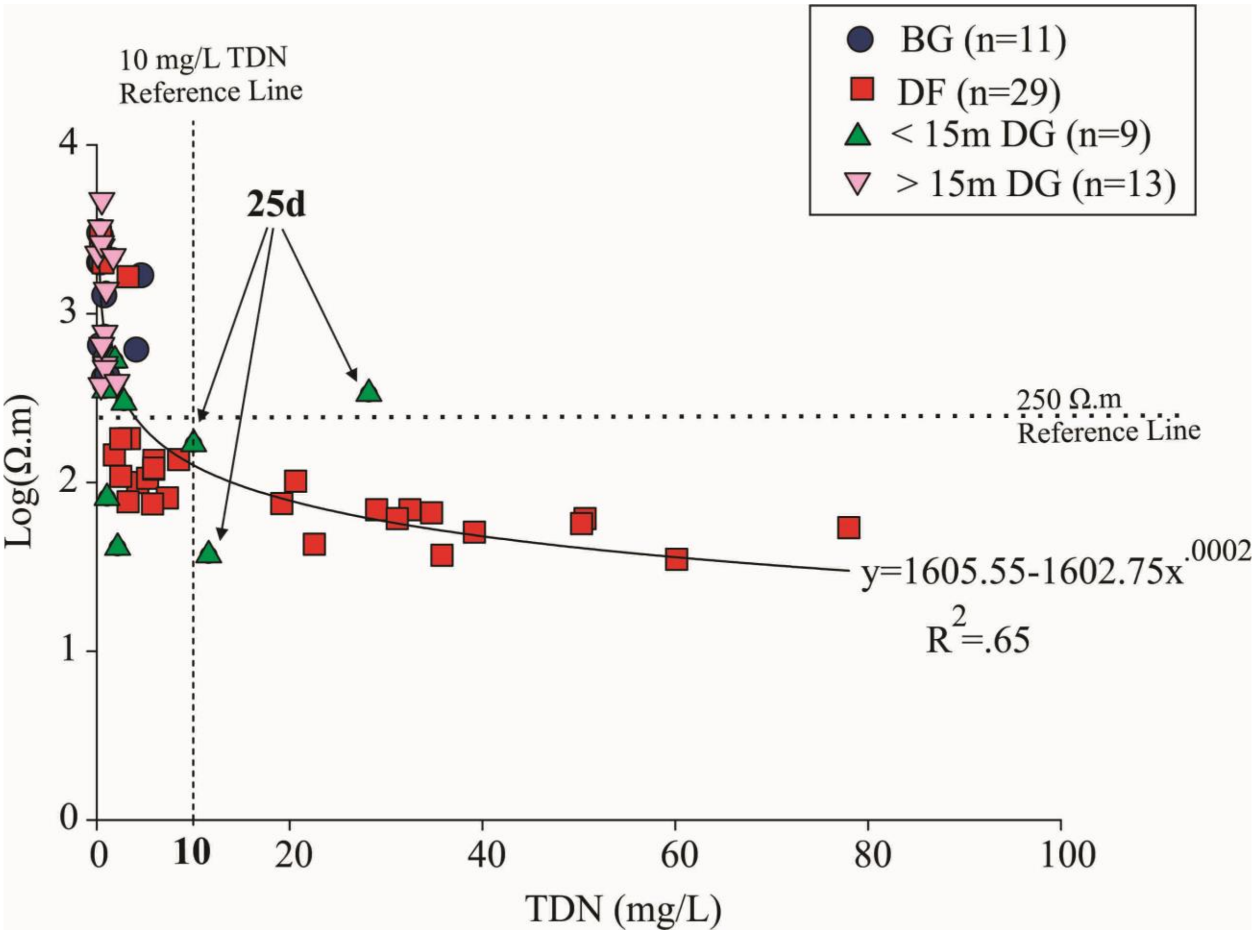
Appendix N Figure 3. Shows Boxplots of TDN and Cl in mg/L collected at the education center from background and drainfield areas, areas less than 15m downgradient of the OWS drainfield, areas greater than 15m downgradient of the OWS drainfield, and from the tank. On each box plot the median values are listed in black, bold fond beside the median line and the mean values are marked by the red diamond on each box plot and the red bold font. The sample numbers (n) are listed below the TDN and Cl markers. The purple dashed line marks the mg/L requirement for drinking water.

Residential 100



Appendix N Figure 4. Shows Boxplots of TDN and Cl in mg/L collected at Residential 100 from background and drainfield areas, areas less than 15m downgradient of the OWS drainfield, areas greater than 15m downgradient of the OWS drainfield, a surface water body (stream) and from the tank. On each box plot the median values are listed in black, bold fond beside the median line and the mean values are marked by the red diamond on each box plot and the red bold font. The sample numbers (n) are listed below the TDN and Cl markers. The purple dashed line marks the mg/L requirement for drinking water.

High School TDN vs. Resistivity



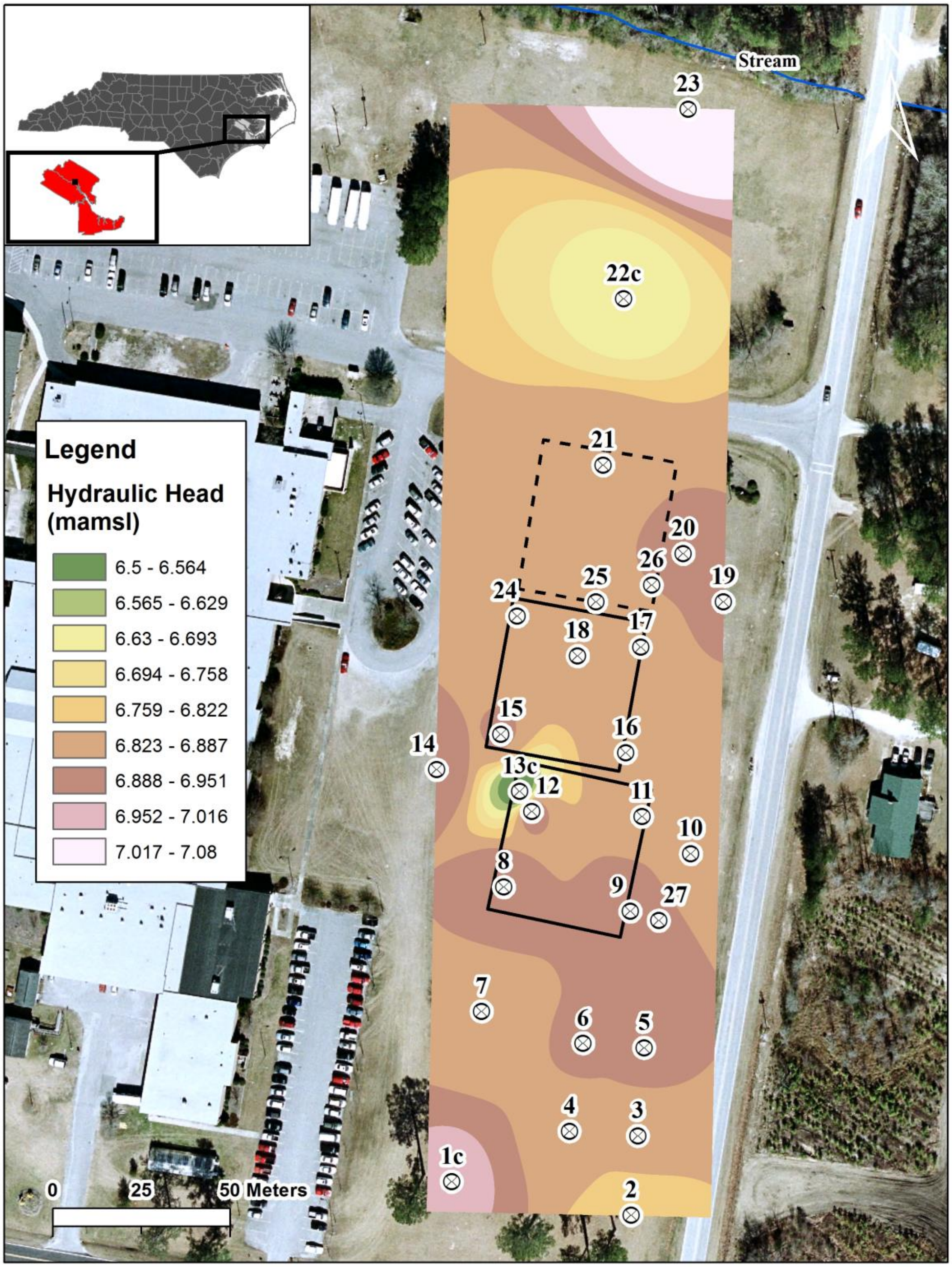
Appendix Figure N5 shows a scatter plot regression analysis of Log resistivity (Ω.m) vs TDN (mg/L) with the regression line (curved solid black line), equation and R^2 value for background (BG), drainfield (DF), <15m downgradient (DG) and >15m downgradient (DG) of the drainfield with the drainfield flow path. The vertical dashed black line is set at 10 mg/L TDN and the horizontal dashed black line is set at 250 Ω.m, both are labeled. In the figure, the values greater than 10 mg/L TDN and less than 250 Ω.m are all sourced from the drainfield and downgradient piezometer 25d; these values are believed to be influenced by wastewater inputs. Future work may be able to use CCR to locate areas characterized by elevated TDN.

Appendix O: Hydraulic Head Contour Maps

The hydraulic gradient maps were generated using hydraulic head averages for piezometers installed at each study site. The hydraulic head averages used in Figures O1-4 were listed in Appendix Table E3. The hydraulic head averages were contoured in ArcGIS using spline. Elevation values were collected during Smith (2013), Iverson (2013), and during the current study. The groundwater flow direction utilized in the current study was calculated using the three point method discussed in the Methods (Heath, 1983). The maps were intended to provide a generalized view of hydraulic gradient at the high school (Figure O1), elementary school (Figure O2), education center (Figure O3) and Residential 100 (Figure O4).

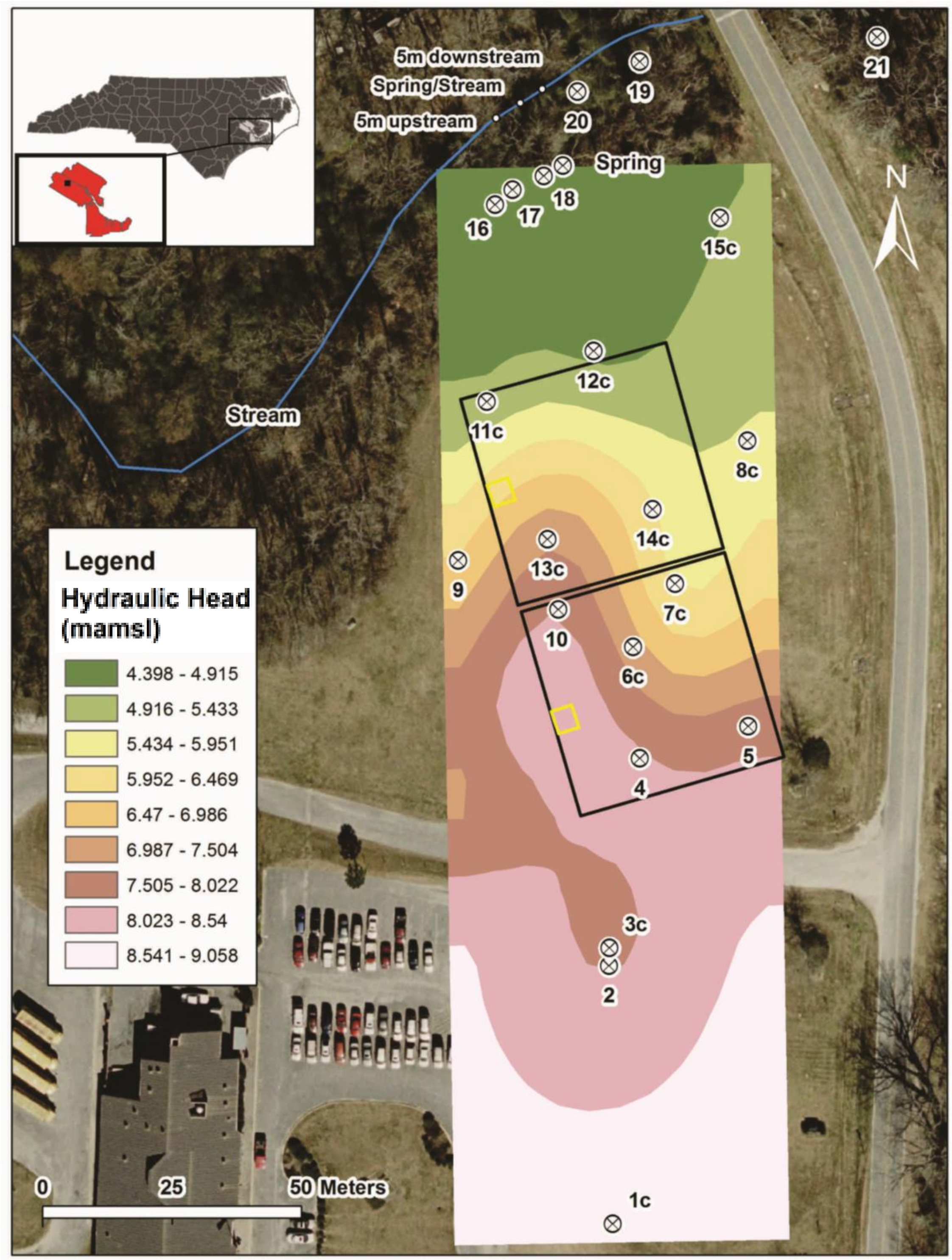
Appendix Figures O1-4 show contoured hydraulic head values at piezometers within the study area at each site. A legend for the hydraulic gradient map is provided on each figure. The blue arrow represents the groundwater flow direction calculated using the 3 point method. Solid, black line rectangles mark the location of the OWS drainfields and the dashed, black lines mark the locations of the de-activated drainfields. The solid, yellow line rectangle marks the location of the distribution box (D-box) at the education center.

High School

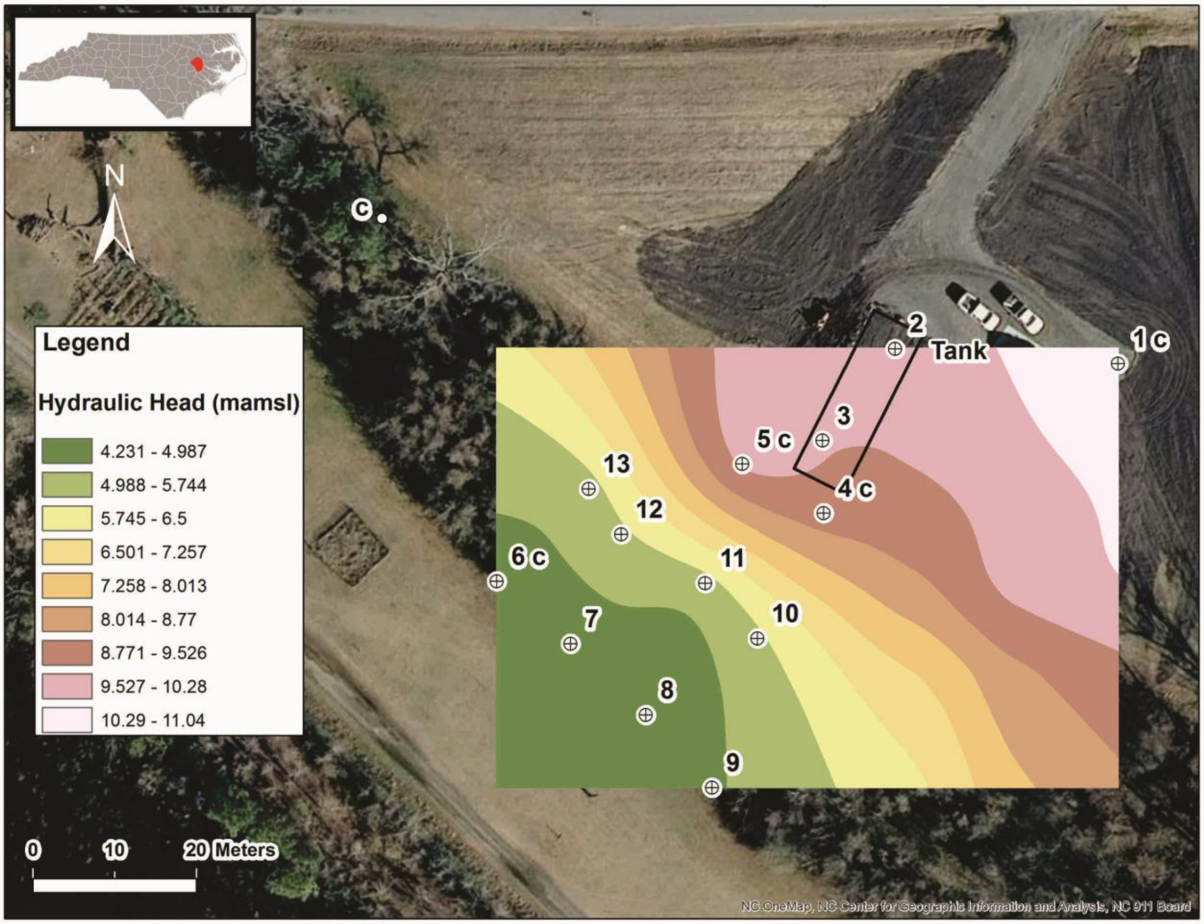


Stream
Legend
Hydraulic Head (mamsl)
6.5 - 6.564
6.565 - 6.629
6.63 - 6.693
6.694 - 6.758
6.759 - 6.822
6.823 - 6.887
6.888 - 6.951
6.952 - 7.016
7.017 - 7.08
0 25 50 Meters
23
22c
21
20
26
19
25
24
17
18
15
16
14
13c
12
11
10
8
9
27
7
6
5
4
3
1c
2

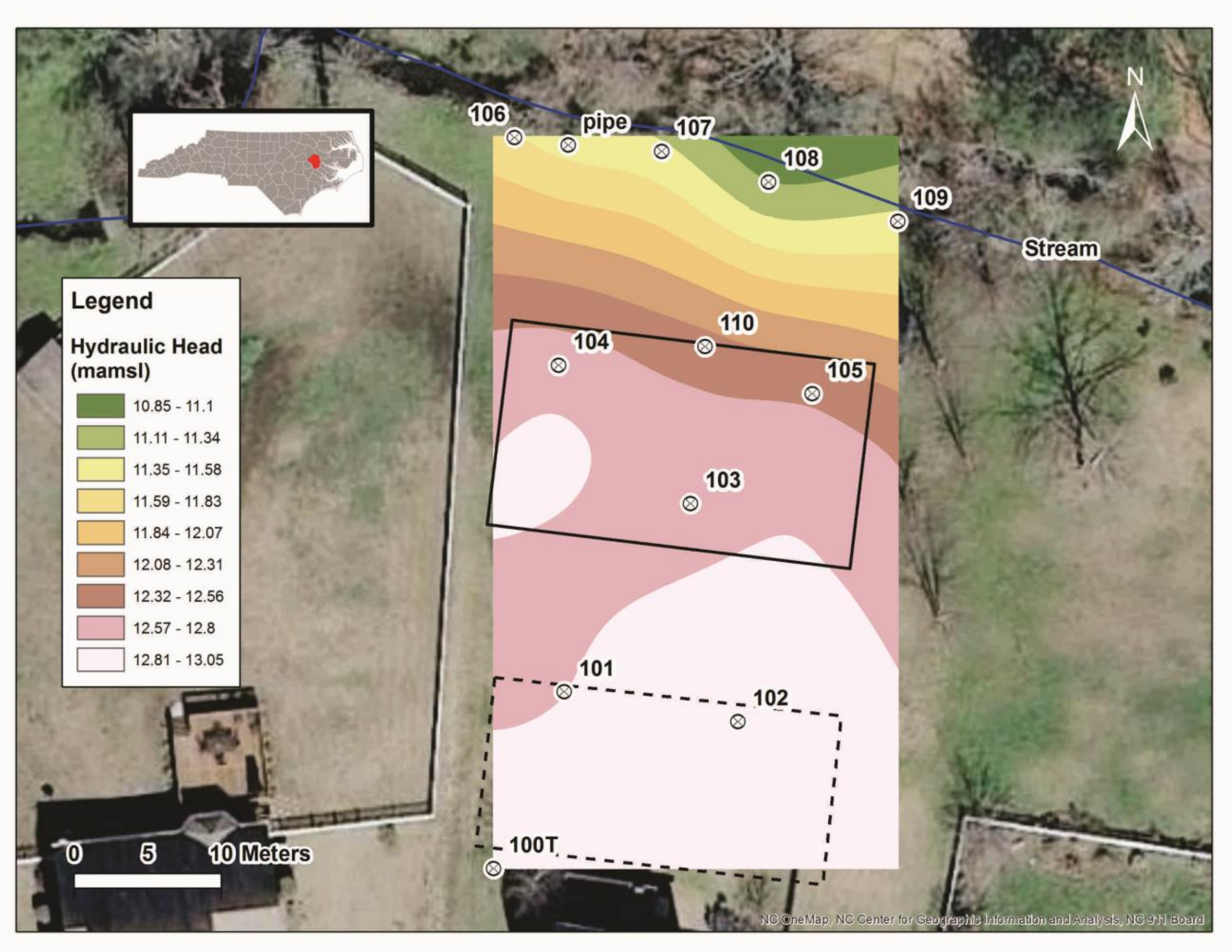
Elementary School



Education Center



Residential 100



Appendix P: CCR Value Depth Sections for Piezometers.

Appendix P1: CCR survey resistivity values with depth sections

CCR survey resistivity values were taken from transects. The information on the tables below include: transect ID, survey date, location of piezometer, piezometer ID, piezometer depth to bottom of the screened interval and piezometer measured horizontal location on the transect. The Y location was the location on the transect that was closest to the piezometer location. The Z value was the depth below the ground surface of piezometer's screened interval. The Z values have negative numbers that represent depth below the ground surface. The Z value was selected based on the depth that fell within the screened interval of a piezometer. The screened interval was approximately 0.91 m for all piezometers. The resistivity values, depth (Z) and location (Y) that were selected for each piezometer and used in objective 1 and 2 were highlighted in light blue in the tables below. The resistivity averages for the whole depth section were also provided. The resistivity depth sections and selected resistivity values were shown for the high school (Figures H1), elementary school (Figures H2), education center (Figure H3), Residential 100 (Figure H4) and supplemental Residential 200-300 (Figure H5).

High School Transect 1

High School Transect 1 (Appendix Figure H1)												
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z)))								
				9/7/2012			11/14/2012			4/10/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
1s	BG	0	1.95	0.9	-0.43	1230	2.17	-0.5	817	-1.5	-0.43	745
1d	BG	0	3.61	0.9	-1.28	1283	2.17	-1.5	612	-1.5	-1.28	650
				0.9	-2.18	1229	2.17	-2.5	853	-1.5	-2.18	851
				0.9	-3.17	1048				-1.5	-3.17	1684
										-1.5	-4.25	6107
Average Ω.m						1198			760			2007
7	BG	48	2.40	48.4	-0.43	4627	47.17	-0.5	3445	48.5	-0.43	2947
				48.4	-1.28	4129	47.17	-1.5	2964	48.5	-1.28	2480
				48.4	-2.18	2893	47.17	-2.5	3048	48.5	-2.18	2012
				48.4	-3.17	1696	47.17	-3.7	3042	48.5	-3.17	1801
				48.4	-4.25	968	47.17	-5.0	774	48.5	-4.25	2632
				48.4	-5.45	821	47.17	-6.5	212	48.5	-5.45	6628
				48.4	-6.76	884				48.5	-6.76	21471
Average Ω.m						2288			2247			5710
8	DF	86	2.44	85.9	-0.43	103	87.17	-0.5	105	86.0	-0.43	124
				85.9	-1.28	93	87.17	-1.5	103	86.0	-1.28	110
				85.9	-2.18	77	87.17	-2.5	101	86.0	-2.18	100
				85.9	-3.17	69	87.17	-3.7	101	86.0	-3.17	150
				85.9	-4.25	75	87.17	-5.0	220	86.0	-4.25	546
				85.9	-5.45	94	87.17	-6.5	379	86.0	-5.45	1989
				85.9	-6.76	109				86.0	-6.76	9875
Average Ω.m						88			168			1842

High School Transect 1 (Appendix Figure H1)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/7/2012			11/14/2012			4/10/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	
12	DF	105	2.50	105.9	-0.43	15491.40	104.67	-0.47	112.50	106	-0.43	45.30	
				105.9	-1.28	5018.40	104.67	-1.45	110.33	106	-1.28	40.56	
				105.9	-2.18	624.37	104.67	-2.54	100.72	106	-2.18	66.02	
				105.9	-3.17	104.50	104.67	-3.73	78.84	106	-3.17	160.91	
				105.9	-4.25	34.70	104.67	-5.04	74.31	106	-4.25	511.02	
				105.9	-5.45	68.56	104.67	-6.48	316.59	106	-5.45	1071.50	
				105.9	-6.76	174.00				106	-6.76	1676.30	
Average Ω.m						3073.70			132.22			510.23	
13s	DF	111	2.50	110.9	-0.43	18496.10	109.67	-0.47	158.22	111	-0.43	77.16	
13d	DF	111	3.60	110.9	-1.28	1180.00	109.67	-1.45	88.13	111	-1.28	70.85	
				110.9	-2.18	135.61	109.67	-2.54	34.82	111	-2.18	61.41	
				110.9	-3.17	50.80	109.67	-3.73	34.65	111	-3.17	54.11	
				110.9	-4.25	57.29	109.67	-5.04	60.75	111	-4.25	50.16	
				110.9	-5.45	109.46	109.67	-6.48	214.25	111	-5.45	45.96	
				110.9	-6.76	201.83				111	-6.76	34.41	
Average Ω.m						2890.16			98.47			56.29	
15	DF	126	2.45	125.9	-0.43	1840.00	127.17	-0.47	80.58	126	-0.43	68.31	
				125.9	-1.28	951.16	127.17	-1.45	80.55	126	-1.28	64.58	
				125.9	-2.18	146.02	127.17	-2.54	80.20	126	-2.18	56.63	
				125.9	-3.17	36.14	127.17	-3.73	78.78	126	-3.17	48.47	
				125.9	-4.25	21.74	127.17	-5.04	67.33	126	-4.25	44.86	
				125.9	-5.45	40.87	127.17	-6.48	64.74	126	-5.45	49.73	
				125.9	-6.76	86.54				126	-6.76	58.90	
Average Ω.m						446.07			75.36			55.93	

High School Transect 1 (Appendix Figure H1)												
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))								
				9/7/2012			11/14/2012			4/10/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
18	DF	150	2.47	150.9	-0.43	225.45	149.67	-0.47	69.04	151	-0.43	49.37
				150.9	-1.28	244.03	149.67	-1.45	68.68	151	-1.28	58.19
				150.9	-2.18	182.51	149.67	-2.54	69.49	151	-2.18	69.05
				150.9	-3.17	97.44	149.67	-3.73	69.71	151	-3.17	78.62
				150.9	-4.25	44.09	149.67	-5.04	69.59	151	-4.25	92.64
				150.9	-5.45	43.13	149.67	-6.48	69.13	151	-5.45	112.87
				150.9	-6.76	71				151	-6.76	144.45
Average Ω.m						129.66			69.27			86.456
24s	DF	160	2.43	160.9	-0.43	174.12	159.67	-0.47	119.6	161	-0.43	59.74
24d	DF	160	3.33	160.9	-1.28	193.43	159.67	-1.45	73.95	161	-1.28	49.63
				160.9	-2.18	182.45	159.67	-2.54	75.19	161	-2.18	43.03
				160.9	-3.17	122.2	159.67	-3.73	75.42	161	-3.17	36.92
				160.9	-4.25	61.71	159.67	-5.04	56.24	161	-4.25	34.55
				160.9	-5.45	48.87	159.67	-6.48	29.23	161	-5.45	32.42
				160.9	-6.76	60.03				161	-6.76	25.78
Average Ω.m						120.4			71.6			40.296
25s	DG	167	2.74	165.9	-0.43	80.19	167.17	-0.47	238.2	166	-0.43	30.81
25m	DG	167	3.64	165.9	-1.28	140.2	167.17	-1.45	515.1	166	-1.28	31.94
25d	DG	167	4.66	165.9	-2.18	298.32	167.17	-2.54	529.3	166	-2.18	41.18
				165.9	-3.17	352.29	167.17	-3.73	529	166	-3.17	81.48
				165.9	-4.25	168.55	167.17	-5.04	37.17	166	-4.25	335.94
				165.9	-5.45	80.97	167.17	-6.48	38.8	166	-5.45	873.46
				165.9	-6.76	55.81				166	-6.76	1645.9
Average						168.05			314.6			434.39

High School Transect 1 (Appendix Figure H1)												
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))								
				9/7/2012			11/14/2012			4/10/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
21	DG	206	2.41	205.9	-0.43	290.09	207.17	-0.47	1356	206	-0.43	468.51
				205.9	-1.28	289.98	207.17	-1.45	1184	206	-1.28	422.81
				205.9	-2.18	504.41	207.17	-2.54	359.9	206	-2.18	377.79
				205.9	-3.17	979.54	207.17	-3.73	165.7	206	-3.17	414.07
				205.9	-4.25	1349.8	207.17	-5.04	46.76	206	-4.25	818.59
				205.9	-5.45	1023.3	207.17	-6.48	42.99	206	-5.45	2256.2
				205.9	-6.76	698.52				206	-6.76	7089.2
Average Ω.m						733.6629			525.9			1692.5
22s	DG	253	1.95	253.4	-0.43	3818.6	252.17	-0.47	4311	253.5	-0.43	3092.2
22d	DG	253	3.56	253.4	-1.28	2506.3	252.17	-1.45	3246	253.5	-1.28	2271.2
				253.4	-2.18	988.19	252.17	-2.54	1812	253.5	-2.18	1249.1
				253.4	-3.17	394.25	252.17	-3.73	963.3	253.5	-3.17	653.74
				253.4	-4.25	229.21	252.17	-5.04	906.4	253.5	-4.25	355.84
				253.4	-5.45	282.89	252.17	-6.48	910.6	253.5	-5.45	288.7
				253.4	-6.76	458.64				253.5	-6.76	311.48
Average Ω.m						1239.726			2025			1174.6
23	DG	300	1.79	300.9	-0.43	2781.5	299.67	-0.47	2186	301	-0.43	8512
				300.9	-1.28	2616.5	299.67	-1.45	2191	301	-1.28	4718.4
				300.9	-2.18	2270.1	299.67	-2.54	2207	301	-2.18	1909.1
				300.9	-3.17	1749.7	299.67	-3.73	2179	301	-3.17	948.14
				300.9	-4.25	996.31	299.67	-5.04	141.5	301	-4.25	687.89
				300.9	-5.45	582.71	299.67	-6.48	31.44	301	-5.45	772.97
				300.9	-6.76	375.28				301	-6.76	886.28
Average Ω.m						1624.586			1489			2633.5

High School Transect 2

High School Transect 2 (Appendix Figure H1)												
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))								
				9/7/2012			11/14/2012			4/10/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
2	BG	0	2.33	1.19	-0.43	369.47	-	-	-	-		
				1.19	-1.28	453.32	-	-	-	-		
				1.19	-2.18	542.89	-	-	-	-		
				1.19	-3.17	519.07	-	-	-	-		
Average Ω.m						471.1875						
3	BG	16	2.30	16.19	-0.43	314.05	-	-	-	-	-	-
				16.19	-1.28	330.57	-	-	-	-	-	-
				16.19	-2.18	416.58	-	-	-	-	-	-
				16.19	-3.17	496.06	-	-	-	-	-	-
				16.19	-4.25	541.31	-	-	-	-	-	-
				16.19	-5.45	608.56	-	-	-	-	-	-
				16.19	-6.76	794.05	-	-	-	-	-	-
Average Ω.m						500.1686						
5	BG	41	2.41	41.19	-0.43	590.7	-	-	-	-	-	-
				41.19	-1.28	479.08	-	-	-	-	-	-
				41.19	-2.18	434.2	-	-	-	-	-	-
				41.19	-3.17	382.57	-	-	-	-	-	-
				41.19	-4.25	305.76	-	-	-	-	-	-
				41.19	-5.45	268.25	-	-	-	-	-	-
				41.19	-6.76	265.98	-	-	-	-	-	-
Average Ω.m						389.5057						-

High School Transect 2 (Appendix Figure H1)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/7/2012			**11/14/2012**			**4/10/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
11	DF	106	2.34	106.2	-0.43	2542.9	-	-	-	-	-	-	
				106.2	-1.28	2736.6	-	-	-	-	-	-	
				106.2	-2.18	2852.4	-	-	-	-	-	-	
				106.2	-3.17	2403.2	-	-	-	-	-	-	
				106.2	-4.25	1299.2	-	-	-	-	-	-	
				106.2	-5.45	634.52	-	-	-	-	-	-	
				106.2	-6.76	310.95	-	-	-	-	-	-	
Average Ω.m						1825.681	-	-	-	-	-	-	
10	OSP	97	2.52	96.19	-0.43	4583.6	-	-	-	-	-	-	
				96.19	-1.28	3920.3	-	-	-	-	-	-	
				96.19	-2.18	3149	-	-	-	-	-	-	
				96.19	-3.17	2649.1	-	-	-	-	-	-	
				96.19	-4.25	2046.1	-	-	-	-	-	-	
				96.19	-5.45	1503.8	-	-	-	-	-	-	
				96.19	-6.76	1092.2	-	-	-	-	-	-	
Average Ω.m						2706.3							
19	OSP	169	2.21	168.7	-0.43	1660.6	-	-	-	-	-	-	
				168.7	-1.28	1384.7	-	-	-	-	-	-	
				168.7	-2.18	1223.5	-	-	-	-	-	-	
				168.7	-3.17	1105.6	-	-	-	-	-	-	
				168.7	-4.25	1085.6	-	-	-	-	-	-	
				168.7	-5.45	1393.5	-	-	-	-	-	-	
				168.7	-6.76	2336.4	-	-	-	-	-	-	
Average Ω.m						1455.7	-	-	-	-	-	-	

High School Transect 2 (Appendix Figure H1)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/7/2012			**11/14/2012**			**4/10/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
27S	OSP	77	2.74	76.19	-0.43	2700.3	-	-	-	-	-	-	
27M	OSP	77	3.64	76.19	-1.28	2999.3	-	-	-	-	-	-	
27D	OSP	77	4.66	76.19	-2.18	3470	-	-	-	-	-	-	
				76.19	-3.17	3077.7	-	-	-	-	-	-	
				76.19	-4.25	1795.9	-	-	-	-	-	-	
				76.19	-5.45	1079.5	-	-	-	-	-	-	
				76.19	-6.76	748.44	-	-	-	-	-	-	
Average Ω.m						2267.306	-	-	-	-	-	-	

High School Transect 3

High School Transect 3 (Appendix Figure H1)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/7/2012			11/14/2012			4/10/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	
7	BG	40.1	2.40	39.99	-0.43	1773.2	-	-	-	-	-	-	
				39.99	-1.28	1972.6	-	-	-	-	-	-	
				39.99	-2.18	2009.4	-	-	-	-	-	-	
				39.99	-3.17	1378.2	-	-	-	-	-	-	
				39.99	-4.25	568.43	-	-	-	-	-	-	
				39.99	-5.45	280.19	-	-	-	-	-	-	
				39.99	-6.76	176.36	-	-	-	-	-	-	
Average Ω.m						1165.483	-	-	-	-	-	-	
14	BG	108	2.19	107.5	-0.43	6329	-	-	-	-	-	-	
				107.5	-1.28	5897.8	-	-	-	-	-	-	
				107.5	-2.18	3595.6	-	-	-	-	-	-	
				107.5	-3.17	1341	-	-	-	-	-	-	
				107.5	-4.25	343.71	-	-	-	-	-	-	
				107.5	-5.45	151.6	-	-	-	-	-	-	
				107.5	-6.76	112.2	-	-	-	-	-	-	
Average Ω.m						2538.701	-	-	-	-	-	-	

High School Transects 4, 5 and 6

High School Transect 4 (Appendix Figure H1)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/7/2012			11/14/2012			4/10/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	
24s	DF	11.6	2.43	13.12	-0.43	113.11	-	-	-	-	-	-	
24d	DF	11.6	3.33	13.12	-1.28	119.65	-	-	-	-	-	-	
				13.12	-2.18	109.13	-	-	-	-	-	-	
				13.12	-3.17	120.03	-	-	-	-	-	-	
				13.12	-4.25	195.18	-	-	-	-	-	-	
				13.12	-5.45	294.88	-	-	-	-	-	-	
Average Ω.m						158.6633	-	-	-	-	-	-	

High School Transect 5 (Appendix Figure H1)												
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Surveys Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))								
				9/7/2012			11/14/2012			4/10/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
21	DG	29	2.41	21.9	-0.43	300.59	-	-	-	-	-	-
				21.9	-1.28	359.9	-	-	-	-	-	-
				21.9	-2.18	477.18	-	-	-	-	-	-
				21.9	-3.17	529.99	-	-	-	-	-	-
				21.9	-4.25	357.44	-	-	-	-	-	-
				21.9	-5.45	195.44	-	-	-	-	-	-
				21.9	-6.76	120.43	-	-	-	-	-	-
Average						334.4243						

High School Transect 6 (Appendix Figure H1)												
8	DF	61.8	2.44	63.12	-0.43	3441.7	-	-	-	-	-	-
				63.12	-1.28	3046.9	-	-	-	-	-	-
				63.12	-2.18	1658.7	-	-	-	-	-	-
				63.12	-3.17	656.73	-	-	-	-	-	-
				63.12	-4.25	219.19	-	-	-	-	-	-
				63.12	-5.45	121.15	-	-	-	-	-	-
				63.12	-6.76	91.49	-	-	-	-	-	-
Average						1319.409	-	-	-	-	-	-
9	DF	98.4	2.48	98.12	-0.43	1681.4	-	-	-	-	-	-
				98.12	-1.28	1894.2	-	-	-	-	-	-
				98.12	-2.18	2007.3	-	-	-	-	-	-
				98.12	-3.17	1602.1	-	-	-		-	-
				98.12	-4.25	780.02	-	-	-	-	-	-
				98.12	-5.45	377.16	-	-	-	-	-	-
				98.12	-6.76	202.55	-	-	-	-	-	-
Average						1220.676	-	-	-	-	-	-

Elementary School Transect 1

Elementary School Transect 1 (Appendix Figure H2)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/10/2012			11/19/2012			3/25/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	
2	BG	51	4.8	52.11	-0.43	1066.1	51.46	-0.47	901.66	50.46	-0.43	1486.3	
				52.11	-1.28	665.03	51.46	-1.41	902.45	50.46	-1.28	1793.4	
				52.11	-2.18	1400.6	51.46	-2.36	2932.2	50.46	-2.18	3271.4	
				52.11	-3.17	3540.9	51.46	-3.32	3541.4	50.46	-3.17	4562.2	
				52.11	-4.25	4120.5	51.46	-4.29	3563.9	50.46	-4.25	2601.1	
				52.11	-5.45	2274.2	51.46	-5.27	3566.3	50.46	-5.45	1026.2	
				52.11	-6.76	1239.4	51.46	-6.27	3564.7	50.46	-6.76	416.02	
							51.46	-7.27	3563.9				
Average Ω.m						2043.819			2817.06			2165.2	
3	BG	54	6.0	54.61	-0.43	733.63	53.96	-0.47	587.86	52.96	-0.43	1641.2	
				54.61	-1.28	1527.8	53.96	-1.41	588.05	52.96	-1.28	2403.6	
				54.61	-2.18	3770.2	53.96	-2.36	3255.6	52.96	-2.18	4654.4	
				54.61	-3.17	4982.7	53.96	-3.32	3569.4	52.96	-3.17	5058	
				54.61	-4.25	2337	53.96	-4.29	3580.8	52.96	-4.25	1472.4	
				54.61	-5.45	826.72	53.96	-5.27	3577.2	52.96	-5.45	326.75	
				54.61	-6.76	332.77	53.96	-6.27	3571.4	52.96	-6.76	79.15	
							53.96	-7.27	3568.5				
Average Ω.m						2072.974			2787.35			2233.6	

Elementary School Transect 1 (Appendix Figure H2)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/10/2012			**11/19/2012**			**3/25/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
4	DF	87	5.0	87.11	-0.43	565.69	86.46	-0.47	4253.5	87.96	-0.43	570.57	
				87.11	-1.28	423.29	86.46	-1.41	595.85	87.96	-1.28	696.28	
				87.11	-2.18	546.49	86.46	-2.36	365.32	87.96	-2.18	863.9	
				87.11	-3.17	444.61	86.46	-3.32	366.46	87.96	-3.17	690.29	
				87.11	-4.25	129.26	86.46	-4.29	382.76	87.96	-4.25	193.05	
				87.11	-5.45	52.98	86.46	-5.27	368.9	87.96	-5.45	55.52	
				87.11	-6.76	44.01	86.46	-6.27	57.13	87.96	-6.76	22.49	
							86.46	-7.27	37.9				
Average Ω.m						315.19			803.478			441.73	
6	DF	113	6.4	112.1	-0.43	1768.2	113.96	-0.47	103.27	113	-0.43	450.71	
				112.1	-1.28	593.9	113.96	-1.41	235.87	113	-1.28	359.98	
				112.1	-2.18	2522.8	113.96	-2.36	236.34	113	-2.18	230.06	
				112.1	-3.17	1580.8	113.96	-3.32	236.43	113	-3.17	135.39	
				112.1	-4.25	98.89	113.96	-4.29	100.19	113	-4.25	73.45	
				112.1	-5.45	30.35	113.96	-5.27	46.18	113	-5.45	53.5	
				112.1	-6.76	108.18	113.96	-6.27	40.7	113	-6.76	49.34	
							113.96	-7.27	40.53				
Average Ω.m						957.5886			129.939			193.2	

Elementary School Transect 1 (Appendix Figure H2)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				9/10/2012			**11/19/2012**			**3/25/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
7	DF	124	6.7	124.6	-0.43	386.03	123.96	-0.47	1113.1	123	-0.43	744.37
				124.6	-1.28	351.54	123.96	-1.41	1108.1	123	-1.28	714.7
				124.6	-2.18	293.15	123.96	-2.36	74.6	123	-2.18	538
				124.6	-3.17	77.04	123.96	-3.32	74.58	123	-3.17	301.09
				124.6	-4.25	15.3	123.96	-4.29	76.49	123	-4.25	120.7
				124.6	-5.45	22.88	123.96	-5.27	108.56	123	-5.45	68.79
				124.6	-6.76	194.2	123.96	-6.27	189.45	123	-6.76	55.8
							123.96	-7.27	221.52			
AVERAGE						191.4486			370.8			363.35
13	DF	135	5.8	134.6	-0.43	227.25	133.96	-0.47	214.79	135.5	-0.43	536.78
			5.9	134.6	-1.28	407.99	133.96	-1.41	407.85	135.5	-1.28	510.55
				134.6	-2.18	564.33	133.96	-2.36	407.57	135.5	-2.18	374.09
				134.6	-3.17	247.99	133.96	-3.32	187.53	135.5	-3.17	269.42
				134.6	-4.25	54.79	133.96	-4.29	48.17	135.5	-4.25	186.62
				134.6	-5.45	37.27	133.96	-5.27	49.56	135.5	-5.45	126.99
				134.6	-6.76	89.76	133.96	-6.27	381.42	135.5	-6.76	76.73
							133.96	-7.27	487.19			
Average Ω.m						232.7686			273.01			297.31

Elementary School Transect 1 (Appendix Figure H2)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/10/2012			11/19/2012			3/25/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	
10	DF	120	4.6	119.6	-0.43	312.84	118.96	-0.47	223.95	120.5	-0.43	530.94	
				119.6	-1.28	410	118.96	-1.41	223.87	120.5	-1.28	574.8	
				119.6	-2.18	462.87	118.96	-2.36	115.47	120.5	-2.18	430.45	
				119.6	-3.17	65.76	118.96	-3.32	112.52	120.5	-3.17	202.76	
				119.6	-4.25	4.32	118.96	-4.29	111.57	120.5	-4.25	62.63	
				119.6	-5.45	2.19	118.96	-5.27	111.58	120.5	-5.45	33.85	
				119.6	-6.76	16.53	118.96	-6.27	111.92	120.5	-6.76	31.04	
							118.96	-7.27	112.13				
Average Ω.m						182.07			140.38			266.64	

Elementary School Transect 2

Elementary School Transect 2 (Appendix Figure H2)													
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))									
				9/10/2012			11/19/2012			3/25/2013			
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
14	DF	62	7.2	61.66	-0.43	406.25	-	-	-	-	-	-
				61.66	-1.28	437.07	-	-	-	-	-	-
				61.66	-2.18	407.82	-	-	-	-	-	-
				61.66	-3.17	233.54	-	-	-	-	-	-
				61.66	-4.25	71.25	-	-	-	-	-	-
				61.66	-5.45	23.97	-	-	-	-	-	-
				61.66	-6.76	8.36	-	-	-	-	-	-
Average Ω.m						226.89						

Elementary School Transect 2 (Appendix Figure H2)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/10/2012			**11/19/2012**			**3/25/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
6	DF	36	6.4	36.66	-0.43	709.15	-	-	-	-	-	-	
				36.66	-1.28	379.23	-	-	-	-	-	-	
				36.66	-2.18	150.86	-	-	-	-	-	-	
				36.66	-3.17	86.78	-	-	-	-	-	-	
				36.66	-4.25	95.3	-	-	-	-	-	-	
				36.66	-5.45	151.81	-	-	-	-	-	-	
				36.66	-6.76	242.16	-	-	-	-	-	-	
Average Ω.m						259.33							
7	DF	47	6.7	46.66	-0.43	168.18	-	-	-	-	-	-	
				46.66	-1.28	123.91	-	-	-	-	-	-	
				46.66	-2.18	108.57	-	-	-	-	-	-	
				46.66	-3.17	128.51	-	-	-	-	-	-	
				46.66	-4.25	88.59	-	-	-	-	-	-	
				46.66	-5.45	23.81	-	-	-	-	-	-	
				46.66	-6.76	3.76	-	-	-	-	-	-	
Average Ω.m						92.19							

Elementary School Transect 3, 5, and 6

Elementary School Transect 3 (Appendix Figure H2)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/10/2012			**11/19/2012**			**3/25/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
9	BG	155	6.8	47.5	-0.43	2191.5	-	-	-	-	-	-	
				47.5	-1.28	2008.8	-	-	-	-	-	-	
				47.5	-2.18	1973.2	-	-	-	-	-	-	
				47.5	-3.17	1458.5	-	-	-	-	-	-	
				47.5	-4.25	797.29	-	-	-	-	-	-	
				47.5	-5.45	544.16	-	-	-	-	-	-	
				47.5	-6.76	451.62	-	-	-	-	-	-	
Average Ω.m						1346.44	-	-	-	-	-	-	

Elementary School Transect 5 (Appendix Figure H2)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				9/10/2012			**11/19/2012**			**3/25/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
9	BG	66	6.8	65.24	-0.43	840.94	-	-	-	-	-	-
				65.24	-1.28	961.28	-	-	-	-	-	-
				65.24	-2.18	1050.2	-	-	-	-	-	-
				65.24	-3.17	930.71	-	-	-	-	-	-
				65.24	-4.25	607.86	-	-	-	-	-	-
				65.24	-5.45	414.84	-	-	-	-	-	-
				65.24	-6.76	314.07	-	-	-	-	-	-
Average Ω.m						731.4143	-	-	-	-	-	-

Elementary School Transect 6 (Appendix Figure H2)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				9/10/2012			**11/19/2012**			**3/25/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
4	DF	19	5.0	19.4	-0.43	1145.4	-	-	-	-	-	-	
				19.4	-1.28	1046.4	-	-	-	-	-	-	
				19.4	-2.18	791.77	-	-	-	-	-	-	
				19.4	-3.17	456.14	-	-	-	-	-	-	
				19.4	-4.25	170.02	-	-	-	-	-	-	
				19.4	-5.45	78.1	-	-	-	-	-	-	
				19.4	-6.76	45.69	-	-	-	-	-	-	
Average Ω.m						533.36	-	-	-	-	-	-	
5	DF	44	5.2	44.4	-0.43	157.11	-	-	-	-	-	-	
				44.4	-1.28	321.52	-	-	-	-	-	-	
				44.4	-2.18	548.08	-	-	-	-	-	-	
				44.4	-3.17	447.86	-	-	-	-	-	-	
				44.4	-4.25	202.13	-	-	-	-	-	-	
				44.4	-5.45	125.06	-	-	-	-	-	-	
				44.4	-6.76	108.56	-	-	-	-	-	-	
Average Ω.m						272.9029							

Education Center Transect 1

Education Center Transect 1 (Appendix Figure H3)																
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**												
				3/23/2012			**9/4/2012**			**11/29/2012**			**4/17/2013**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
1	BG	0	3.9	2.09	-0.43	860.8	2.01	-0.43	628	2.52	-0.47	1250	2.1	-0.5	738	
			5.4	2.09	-1.28	754.7	2.01	-1.28	459	2.52	-1.45	1249	2.1	-1.4	362	
*Please note this piezometer exceeds 10m from the transect				2.09	-2.18	457.3	2.01	-2.18	284	2.52	-2.54	181.5	2.1	-2.4	199	
				2.09	-3.17	273.3	2.01	-3.17	186	2.52	-3.73	92.41	2.1	-3.3	178	
				2.09	-4.25	221.8	2.01	-4.25	167	2.52	-5.04	92.67	2.1	-4.3	179	
													2.1	-5.3	200	
Average						513.6			345			573.1			309	

Education Center Transect 1 (Appendix Figure H3)															
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**											
				3/23/2012			**9/4/2012**			**11/29/2012**			**4/17/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
3	DF	23	4.5	22.09	-0.43	1119	22	-0.43	1069	22.52	-0.47	3149	22.1	-0.5	868
				22.09	-1.28	1335	22	-1.28	1092	22.52	-1.45	3149	22.1	-1.4	868
				22.09	-2.18	1293	22	-2.18	778	22.52	-2.54	3140	22.1	-2.4	814
				22.09	-3.17	387.4	22	-3.17	409	22.52	-3.73	2346	22.1	-3.3	217
				22.09	-4.25	42.18	22	-4.25	156	22.52	-5.04	281.2	22.1	-4.3	48
				22.09	-5.45	8.14	22	-5.45	81.4	22.52	-6.48	200.7	22.1	-5.3	36.6
				22.09	-6.76	4.45	22	-6.76	55.1				22.1	-6.3	36.1
													22.1	-7.3	35.9
													22.1	-8.3	25.2
Average Ω.m						598.5			520			2044			328
4	DG	17	5.7	17.09	-0.43	1593	17	-0.43	1291	17.52	-0.47	2820	17.1	-0.5	1021
				17.09	-1.28	1326	17	-1.28	800	17.52	-1.45	1186	17.1	-1.4	858
				17.09	-2.18	464.9	17	-2.18	427	17.52	-2.54	320	17.1	-2.4	568
				17.09	-3.17	68.73	17	-3.17	236	17.52	-3.73	207	17.1	-3.3	157
				17.09	-4.25	30.2	17	-4.25	128	17.52	-5.04	123	17.1	-4.3	41.9
				17.09	-5.45	199.3	17	-5.45	87	17.52	-6.48	117	17.1	-5.3	33.2
				17.09	-6.76	2973	17	-6.76	69.7				17.1	-6.3	31.2
Average Ω.m						950.7			434			795.5			387

Education Center Transect 1 (Appendix Figure H3)															
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**											
				3/23/2012			**9/4/2012**			**11/29/2012**			**4/17/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
5	DG	27	5.3	27.09	-0.43	858.3	27	-0.43	482	27.52	-0.47	2150	27.1	-0.5	602
				27.09	-1.28	2874	27	-1.28	544	27.52	-1.45	2183	27.1	-1.4	1864
				27.09	-2.18	3517	27	-2.18	426	27.52	-2.54	1203	27.1	-2.4	1866
				27.09	-3.17	1238	27	-3.17	233	27.52	-3.73	178	27.1	-3.3	1863
				27.09	-4.25	128.1	27	-4.25	86	27.52	-5.04	47	27.1	-4.3	25.4
				27.09	-5.45	88.61	27	-5.45	41	27.52	-6.48	65.65	27.1	-5.3	25.7
				27.09	-6.76	445	27	-6.76	24				27.1	-6.3	26.8
													27.1	-7.3	41.1
													27.1	-8.3	51.9
Average Ω.m						1307			262			971.2			707

Education Center Transect 3, 5, and 6

Education Center Transect 3 (Appendix Figure H3)															
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))											
				3/23/2012			9/4/2012			11/29/2012			4/17/2013		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
2	DF	22.5	3.8	24.28	-0.43	1012	24.5	-0.43	2351	24.91	-0.47	2822	24.44	-0.5	3485
			4.4	24.28	-1.28	1187	24.5	-1.28	1657	24.91	-1.45	2828	24.44	-1.4	3161
				24.28	-2.18	990	24.5	-2.18	625	24.91	-2.54	2971	24.44	-2.4	615
				24.28	-3.17	1011	24.5	-3.17	283	24.91	-3.73	161	24.44	-3.3	615
				24.28	-4.25	628	24.5	-4.25	160	24.91	-5.04	39	24.44	-4.3	614
				24.28	-5.45	217	24.5	-5.45	121	24.91	-6.48	39	24.44	-5.3	600
				24.28	-6.76	66	24.5	-6.76	103				24.44	-6.3	410
													24.44	-7.3	339
													24.44	-8.3	329
Average Ω.m						730.3			757			1477			1130
3	DF	10	4.5	9.28	-0.43	1304	9.52	-0.43	802	9.91	-0.47	1548	9.44	-0.5	212
				9.28	-1.28	866.7	9.52	-1.28	585	9.91	-1.45	1711	9.44	-1.4	271
				9.28	-2.18	684.4	9.52	-2.18	477	9.91	-2.54	1709	9.44	-2.4	271
				9.28	-3.17	475.2	9.52	-3.17	306	9.91	-3.73	600.2	9.44	-3.3	271
				9.28	-4.25	202.4	9.52	-4.25	131	9.91	-5.04	29.32	9.44	-4.3	268
				9.28	-5.45	86.46	9.52	-5.45	61.1				9.44	-5.3	250
Average Ω.m						603.2			394			1120			257

Education Center Transect 5 (Appendix Figure H3)									
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**					
				9/4/2012			**12/11/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
6	DG	2.6	2.5	2.17	-0.43	969	2.32	-0.47	1316
				2.17	-1.28	733	2.32	-1.45	1200
				2.17	-2.18	428	2.32	-2.54	1109
				2.17	-3.17	226	2.32	-3.73	570
				2.17	-4.25	110	2.32	-5.04	58
Average Ω.m						493			851
7	DG	14.5	2.7	14.67	-0.43	1309	14.82	-0.47	1441
				14.67	-1.28	904	14.82	-1.45	1409
				14.67	-2.18	393	14.82	-2.54	378
				14.67	-3.17	153	14.82	-3.73	52
				14.67	-4.25	60	14.82	-5.04	18
				14.67	-5.45	36	14.82	-6.48	18
				14.67	-6.76	29			
Average Ω.m						412			553
8	DG	27	3.8	27.17	-0.43	2722	27.32	-0.47	2361
				27.17	-1.28	2771	27.32	-1.45	2361
				27.17	-2.18	1487	27.32	-2.54	2358
				27.17	-3.17	542	27.32	-3.73	991
				27.17	-4.25	129	27.32	-5.04	10
				27.17	-5.45	57	27.32	-6.48	91
				27.17	-6.76	49			
Average Ω.m						1108			1362
9	DG	39	2.5	39.67	-0.43	196	39.82	-0.47	182
				39.67	-1.28	174	39.82	-1.45	182
				39.67	-2.18	141	39.82	-2.54	182
				39.67	-3.17	114	39.82	-3.73	179
				39.67	-4.25	95	39.82	-5.04	59
				39.67	-5.45	88	39.82	-6.48	12
				39.67	-6.76	87			
Average Ω.m						128			133

Education Center Transect 6 (Appendix Figure H3)									
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**					
				9/4/2012			**12/11/2013**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
10	DG	0	3.4	1.99	-0.43	155.3	2.48	-0.47	256.5
				1.99	-1.28	138.9	2.48	-1.45	256.9
				1.99	-2.18	101.5	2.48	-2.54	150.9
				1.99	-3.17	69.25	2.48	-3.73	57.03
				1.99	-4.25	56.54	2.48	-5.04	42.17
Average Ω.m						104.3			152.7
11	DG	9	2.3	9.49	-0.43	76.09	9.98	-0.47	76.09
			3.5	9.49	-1.28	86.02	9.98	-1.45	68.33
				9.49	-2.18	84.05	9.98	-2.54	61.06
				9.49	-3.17	67.85	9.98	-3.73	57.39
				9.49	-4.25	39.77	9.98	-5.04	26.91
				9.49	-5.45	22.75			
Average Ω.m						62.76			57.96
12	DG	21	3	21.99	-0.43	71.76	19.98	-0.47	48.78
			3.9	21.99	-1.28	71.63	19.98	-1.45	48.78
				21.99	-2.18	68.21	19.98	-2.54	48.81
				21.99	-3.17	60.3	19.98	-3.73	48.86
				21.99	-4.25	50.09	19.98	-5.04	49
				21.99	-5.45	44.93	19.98	-6.48	49.05
				21.99	-6.76	42.31			
Average Ω.m						58.46			48.88
13	DG	28	3.1	29.49	-0.43	78.38	29.98	-0.47	97.94
				29.49	-1.28	77.02	29.98	-1.45	93.43
				29.49	-2.18	74.52	29.98	-2.54	53.35
				29.49	-3.17	72.17	29.98	-3.73	29.9
				29.49	-4.25	67.42	29.98	-5.04	18.81
				29.49	-5.45	62.8	29.98	-6.48	16.29
				29.49	-6.76	59.99			
Average Ω.m						70.33			51.62

Residential 100 Transects 1, 2, and 3

Residential 100 Transect 3 (Appendix Figure H4)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				3/27/2013			**7/16/2012**			**11/16/2012**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
101	BG	6	2.5	7.06	-0.43	141	7.1	-0.43	592	7.03	-0.47	127
				7.06	-1.28	118	7.1	-1.28	52	7.03	-1.41	126
				7.06	-2.18	117	7.1	-2.18	19	7.03	-2.36	126
				7.06	-3.17	140	7.1	-3.17	39	7.03	-3.32	127
				7.06	-4.25	189	7.1	-4.25	136	7.03	-4.29	135
Average Ω.m						141			167			128
102	BG	18.5	2.3	19.56	-0.43	92	19.6	-0.43	111	19.53	-0.47	132
				19.56	-1.28	92	19.6	-1.28	122	19.53	-1.41	134
				19.56	-2.18	98	19.6	-2.18	152	19.53	-2.36	189
				19.56	-3.17	92	19.6	-3.17	189	19.53	-3.32	189
				19.56	-4.25	66	19.6	-4.25	207	19.53	-4.29	188
							19.6	-5.45	168	19.53	-5.27	180
							19.6	-6.76	123	19.53	-6.27	136
										19.53	-7.27	49
Average Ω.m						87.79			153.1			149.4

Residential 100 Transect 2 (Appendix Figure H4)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				3/27/2013			**7/16/2012**			**11/16/2012**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
103	DF	12.3	1.6	12.37	-0.43	189	12.61	-0.43	51	11.9	-0.47	72
				12.37	-1.28	174	12.61	-1.28	73	11.9	-1.41	107
				12.37	-2.18	151	12.61	-2.18	74	11.9	-2.36	148
				12.37	-3.17	127	12.61	-3.17	56	11.9	-3.32	157
				12.37	-4.25	98	12.61	-4.25	64	11.9	-4.29	157
							12.61	-5.45	125	11.9	-5.27	154
Average Ω.m						148			74			133
104	DF	2.6	2.2	2.37	-0.43	65	2.61	-0.43	58	1.9	-0.47	40
				2.37	-1.28	69	2.61	-1.28	61	1.9	-1.41	41
				2.37	-2.18	81	2.61	-2.18	128	1.9	-2.36	41
				2.37	-3.17	106	2.61	-3.17	344	1.9	-3.32	41
							2.61	-4.25	1738	1.9	-4.29	39
Average Ω.m						80			466			41
105	DF	20.2	1.2	19.87	-0.43	71	20.11	-0.43	101	19.4	-0.47	86
				19.87	-1.28	76	20.11	-1.28	84	19.4	-1.41	96
				19.87	-2.18	102	20.11	-2.18	82	19.4	-2.36	148
				19.87	-3.17	150	20.11	-3.17	100	19.4	-3.32	154
				19.87	-4.25	231	20.11	-4.25	153	19.4	-4.29	154
							20.11	-5.45	201	19.4	-5.27	153
							20.11	-6.76	223	19.4	-6.27	109
										19.4	-7.27	51
Average Ω.m						126			135			119

Residential 100 Transect 2 (Appendix Figure H4)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				3/27/2013			**7/16/2012**			**11/16/2012**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
110	DF	13	1.6	14.87	-0.43	113	12.61	-0.43	51	14.4	-0.47	100
			2.5	14.87	-1.28	119	12.61	-1.28	73	14.4	-1.41	101
				14.87	-2.18	129	12.61	-2.18	74	14.4	-2.36	137
				14.87	-3.17	142	12.61	-3.17	56	14.4	-3.32	157
				14.87	-4.25	156	12.61	-4.25	64	14.4	-4.29	157
							12.61	-5.45	125	14.4	-5.27	156
Average Ω.m						132			74			135

Residential Transect 1 (Appendix Figure H4)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				3/27/2013			**7/16/2012**			**11/16/2012**		
				Y	Z	Ω.m	Y	Z	Ω.m	Y	Z	Ω.m
106	DG	14.9	2.4	14.78	-0.43	203	14.4	-0.43	43	14.26	-0.47	131
				14.78	-1.28	231	14.4	-1.28	103	14.26	-1.41	131
				14.78	-2.18	230	14.4	-2.18	334	14.26	-2.36	132
				14.78	-3.17	176	14.4	-3.17	775	14.26	-3.32	134
				14.78	-4.25	88	14.4	-4.25	572	14.26	-4.29	171
							14.4	-5.45	147	14.26	-5.27	171
							14.4	-6.76	29			
Average Ω.m						186			286			145

Residential Transect 1 (Appendix Figure H4)												
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**								
				3/27/2013			**7/16/2012**			**11/16/2012**		
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**
pipe	DG	18.6	-	19.78	-0.43	129	19.4	-0.43	75	19.26	-0.47	107
				19.78	-1.28	121	19.4	-1.28	117	19.26	-1.41	140
				19.78	-2.18	149	19.4	-2.18	174	19.26	-2.36	191
				19.78	-3.17	158	19.4	-3.17	193	19.26	-3.32	212
				19.78	-4.25	91	19.4	-4.25	152	19.26	-4.29	221
							19.4	-5.45	92	19.26	-5.27	221
							19.4	-6.76	54	19.26	-6.27	137
										19.26	-7.27	56
Average Ω.m						130			122			161
107	DG	24	1.5	24.78	-0.43	83	24.4	-0.43	110	24.26	-0.47	93
			2.5	24.78	-1.28	118	24.4	-1.28	69	24.26	-1.41	93
				24.78	-2.18	203	24.4	-2.18	99	24.26	-2.36	118
				24.78	-3.17	251	24.4	-3.17	181	24.26	-3.32	129
				24.78	-4.25	154	24.4	-4.25	232	24.26	-4.29	132
							24.4	-5.45	174	24.26	-5.27	132
							24.4	-6.76	112	24.26	-6.27	116
										24.26	-7.27	38
Average Ω.m						162			139			106

Residential Transect 1 (Appendix Figure H4)													
Piezometer ID	**Location**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: Y (location on transect), Z (penetration depth), and Ω.m (corresponding resistivity value at point (Y, Z))**									
				3/27/2013			**7/16/2012**			**11/16/2012**			
				Y	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	**Y**	**Z**	**Ω.m**	
108	DG	32.6	1.2	32.28	-0.43	125	31.9	-0.43	50	31.76	-0.47	119	
			1.9	32.28	-1.28	125	31.9	-1.28	41	31.76	-1.41	76	
			2.4	32.28	-2.18	156	31.9	-2.18	85	31.76	-2.36	76	
				32.28	-3.17	175	31.9	-3.17	215	31.76	-3.32	79	
				32.28	-4.25	122	31.9	-4.25	396	31.76	-4.29	129	
							31.9	-5.45	362	31.76	-5.27	139	
							31.9	-6.76	270	31.76	-6.27	143	
										31.76	-7.27	166	
Average Ω.m						141			203			116	
109	DG	42	1.6	42.28	-0.43	157	41.9	-0.43	103	41.76	-0.47	114	
			2.1	42.28	-1.28	74	41.9	-1.28	93	41.76	-1.41	116	
				42.28	-2.18	58	41.9	-2.18	153	41.76	-2.36	116	
				42.28	-3.17	78	41.9	-3.17	276	41.76	-3.32	116	
				42.28	-4.25	131	41.9	-4.25	283	41.76	-4.29	79	
							41.9	-5.45	140	41.76	-5.27	68	
							41.9	-6.76	57	41.76	-6.27	65	
										41.76	-7.27	63	
Average Ω.m						100			158			92	

Supplemental Residential: 300, 400, and 200

Supplemental Residential 200 Transect 1 (Appendix Figure H5)						
PZ. ID	Loc.	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: 9/17/2012		
				Y	Z	Ω.m
207	14.5	DG	1.5	14.86	-0.47	81.96
			2.3	14.86	-1.45	84.34
				14.86	-2.54	126.38
				14.86	-3.73	126.28
				14.86	-5.04	65.64
				14.86	-6.48	13.43
Average						83.01
209	11	DG	2.1	12.36	-0.47	89.63
				12.36	-1.45	89.64
				12.36	-2.54	102.82
				12.36	-3.73	102.84
				12.36	-5.04	70.55
				12.36	-6.48	63.79
Average						86.55
211	4	DG	2.1	4.86	-0.47	91.08
				4.86	-1.45	92.4
				4.86	-2.54	92.35
				4.86	-3.73	89.13
				4.86	-5.04	82.1
Average						89.41
212	24	DG	1.3	24.86	-0.47	125.4
			2.1	24.86	-1.45	125.45
				24.86	-2.54	125.62
				24.86	-3.73	126.38
				24.86	-5.04	155.92
				24.86	-6.48	196.22
Average						142.50
213	29	DG	2.1	29.86	-0.47	263.2
				29.86	-1.45	262.85
				29.86	-2.54	261.82
				29.86	-3.73	261.46
				29.86	-5.04	191.93
				29.86	-6.48	186.61
Average						237.98

Supplemental Residential 300 Transect 1 (Appendix Figure H6)						
PZ. ID	**Loc.**	**Y Location of Piezometer on Transect (m)**	**DTB of Screen (m)**	**CCR Survey Data: 9/17/2012**		
				Y	**Z**	**Ω.m**
300	21	BG	3.4	19.92	-0.47	214.53
				19.92	-1.45	233.46
				19.92	-2.54	234.31
				19.92	-2.54	234.31
				19.92	-3.73	193.99
				19.92	-6.48	116.09
Average						204.448
301	27.5	DF	1.7	27.42	-0.47	89.6
				27.42	-1.45	90.31
				27.42	-2.54	98.49
				27.42	-3.73	117.42
				27.42	-5.04	204.95
				27.42	-6.48	205.07
Average						134.307
302	27.2	DF	2.4	27.42	-0.47	89.6
				27.42	-1.45	90.31
				27.42	-2.54	98.49
				27.42	-3.73	117.42
				27.42	-5.04	204.95
				27.42	-6.48	205.07
Average						134.307
303	37.9	DF	2.5	37.42	-0.47	77.56
				37.42	-1.45	77.53
				37.42	-2.54	84.01
				37.42	-3.73	458.16
				37.42	-5.04	1640.1
				37.42	-6.48	21815
Average						4025.39

Supplemental Residential 300 Transect 1 (Appendix Figure H5)						
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data: 9/17/2012		
				Y	Z	Ω.m
305	48.5	DF	2.8	49.92	-0.47	61.36
				49.92	-1.45	80.39
				49.92	-2.54	90.53
				49.92	-3.73	90.04
				49.92	-5.04	22.88
				49.92	-6.48	18.33
Average						60.5883

Supplemental Residential 400 Transect 1 (Appendix Figure H7)						
Piezometer ID	Location	Y Location of Piezometer on Transect (m)	DTB of Screen (m)	CCR Survey Data 9/17/2012		
				Y	Z	Ω.m
403	25	BG	4.2	24.53	-0.47	89.36
				24.53	-1.45	90.14
				24.53	-2.54	389.69
				24.53	-3.73	652.94
				24.53	-5.04	612.86
				24.53	-6.48	9.23
Average						307.37
401	21	DF	4.1	22.03	-0.47	69.3
				22.03	-1.45	69.32
				22.03	-2.54	376.54
				22.03	-3.73	737.85
				22.03	-5.04	648.14
				22.03	-6.48	9.41
Average						318.427
402	37.8	DF	4.0	37.03	-0.47	88.88
				37.03	-1.45	88.84
				37.03	-2.54	104.17
				37.03	-3.73	160.96
				37.03	-5.04	182.46
				37.03	-6.48	107.53
Average						122.14

Appendix Q: Objective 1 Additional Results and Discussion

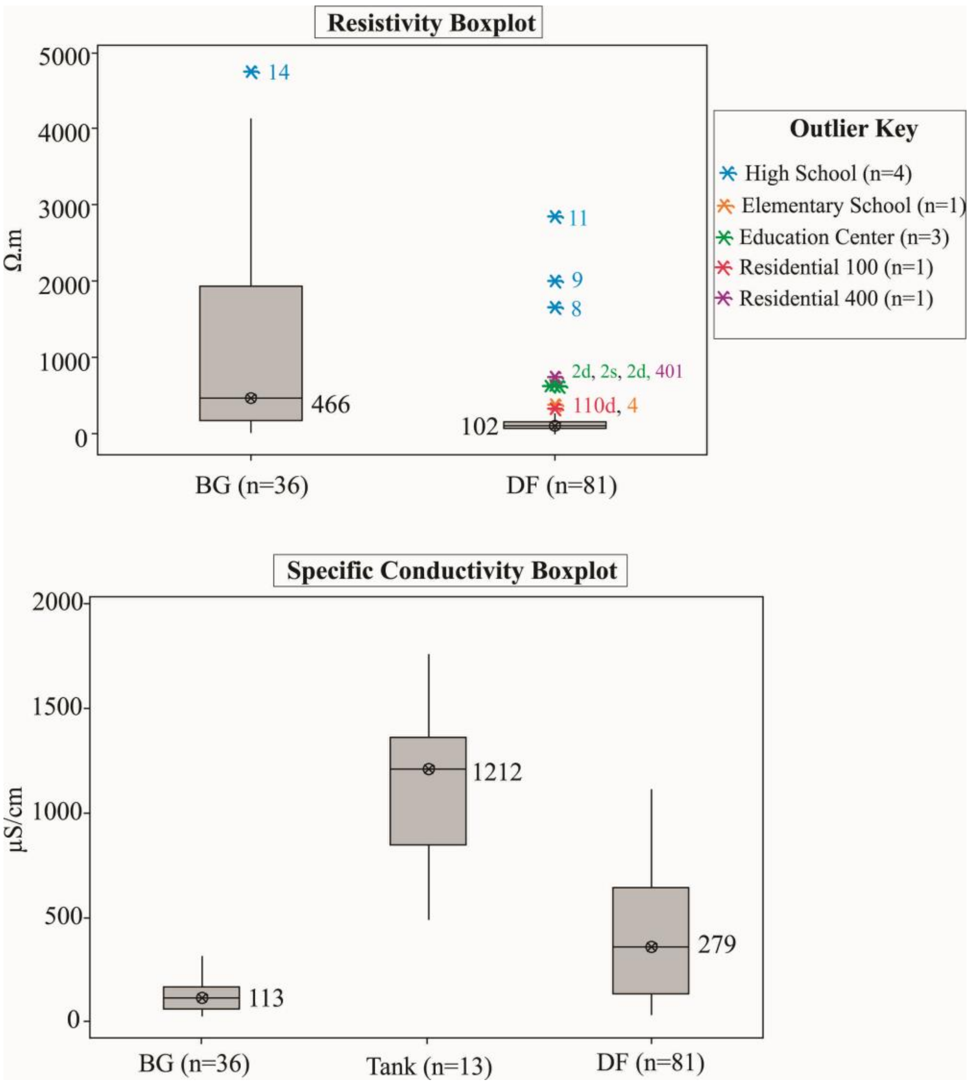
Objective 1, regression analyses were completed for pooled data and individual sites. The regression analysis compared groundwater specific conductivity and resistivity values collected from background and drainfield locations. The measured and theoretical regression analysis equations for the pooled data set and individual sites were listed in Table Q1.

Appendix Table Q1. Pooled and individual site datasets measured regression and theoretical regression analysis equations. The data sets consisted of background and drainfield groundwater specific conductivity and Log resistivity values. The R^2 values and sample numbers for the measured regression equations are listed in Table 4. The measured regression equation y equals the measured Log resistivity value collected from a CCR survey, and the x equals the measured groundwater specific conductivity value collected in the field (values are located in Appendix Table F1 and also Appendix T). The theoretical regression analysis y = the measured resistivity value collected from a CCR survey and x = the calculated pore water specific conductivity (Appendix T).

Site	Measured Regression Equation	Theoretical Regression Equation
All Sites	$y=4.1683-0.3631(\ln\|x\|)$	$y=32500x^{-1}$
High School	$y=5.2655-0.5462(\ln\|x\|)$	$y=30900x^{-1}$
Elementary School	$y=6.2192-.6829(\ln\|x\|)$	$y=34000x^{-1}$
Education Center	$y=1.33376E-5x^2-.034x+2.3719$	$y=31900x^{-1}$
Residential 100	$y=-5.1376-.0034x^{.011}$	$y=30900x^{-1}$

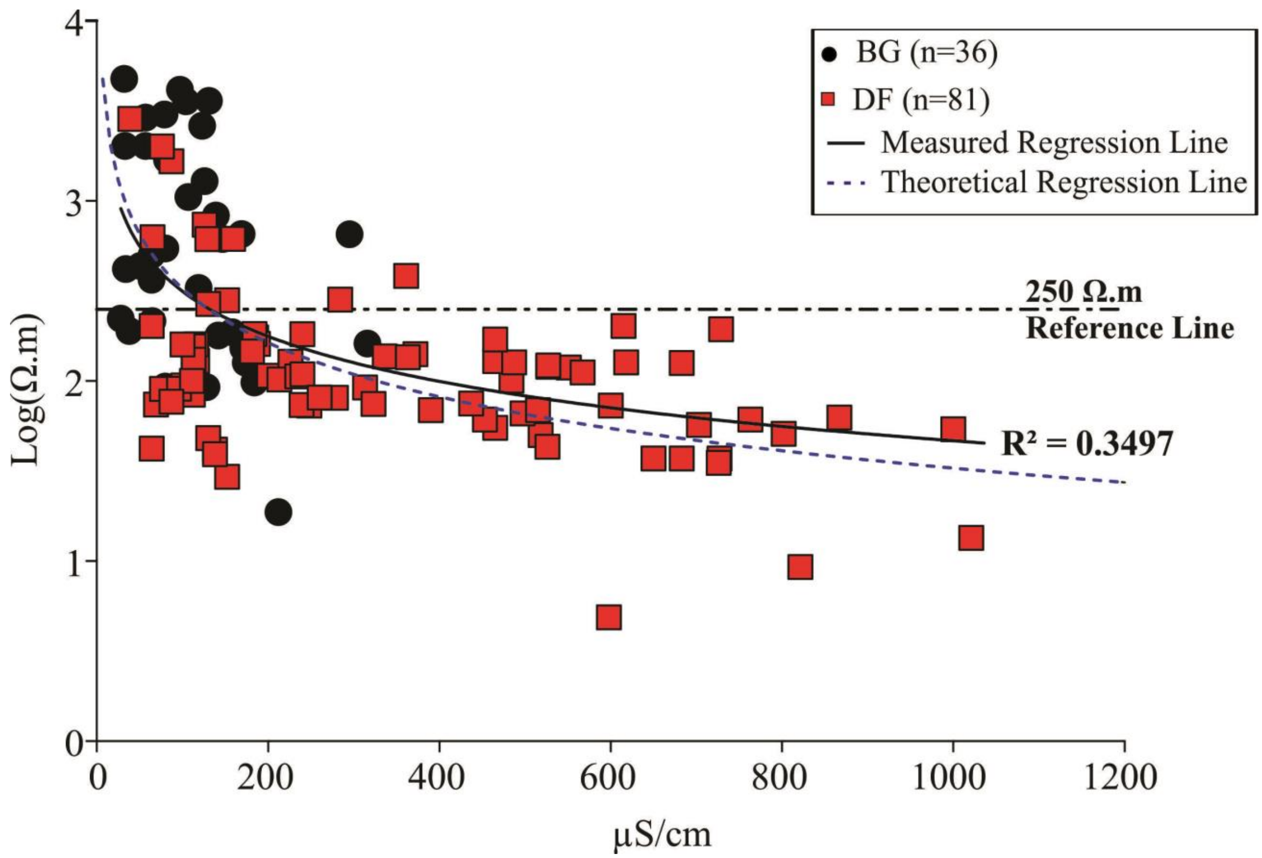
Objective 1 Results: Pooled Data

The pooled data set consisted of values collected from the elementary school, high school, Residential 100, education center, and supplemental residential sites 300 and 400 (Table 4). The drainfield was characterized by an elevated groundwater specific conductivity median and a low resistivity median relative to the background medians (Appendix Figure Q1). The contrasts between median values collected from background and drainfield locations were the third highest in Table 4 (166 µS/cm and 364 Ω.m).



Appendix Figure Q1. Boxplot of pooled groundwater specific conductivity (µS/cm) and resistivity (Ω.m) data collected from the tank/distribution box (Tank), background (BG) and drainfield (DF) areas (Appendix Table F1). Median values are listed beside the median line and symbol on each boxplot. Sample numbers (n) are listed in parenthesis below the x axis. The outliers are color coded and labeled with the piezometer ID number and site; outlier values are located in Appendix Table G1; there were no Residential 300 outliers.

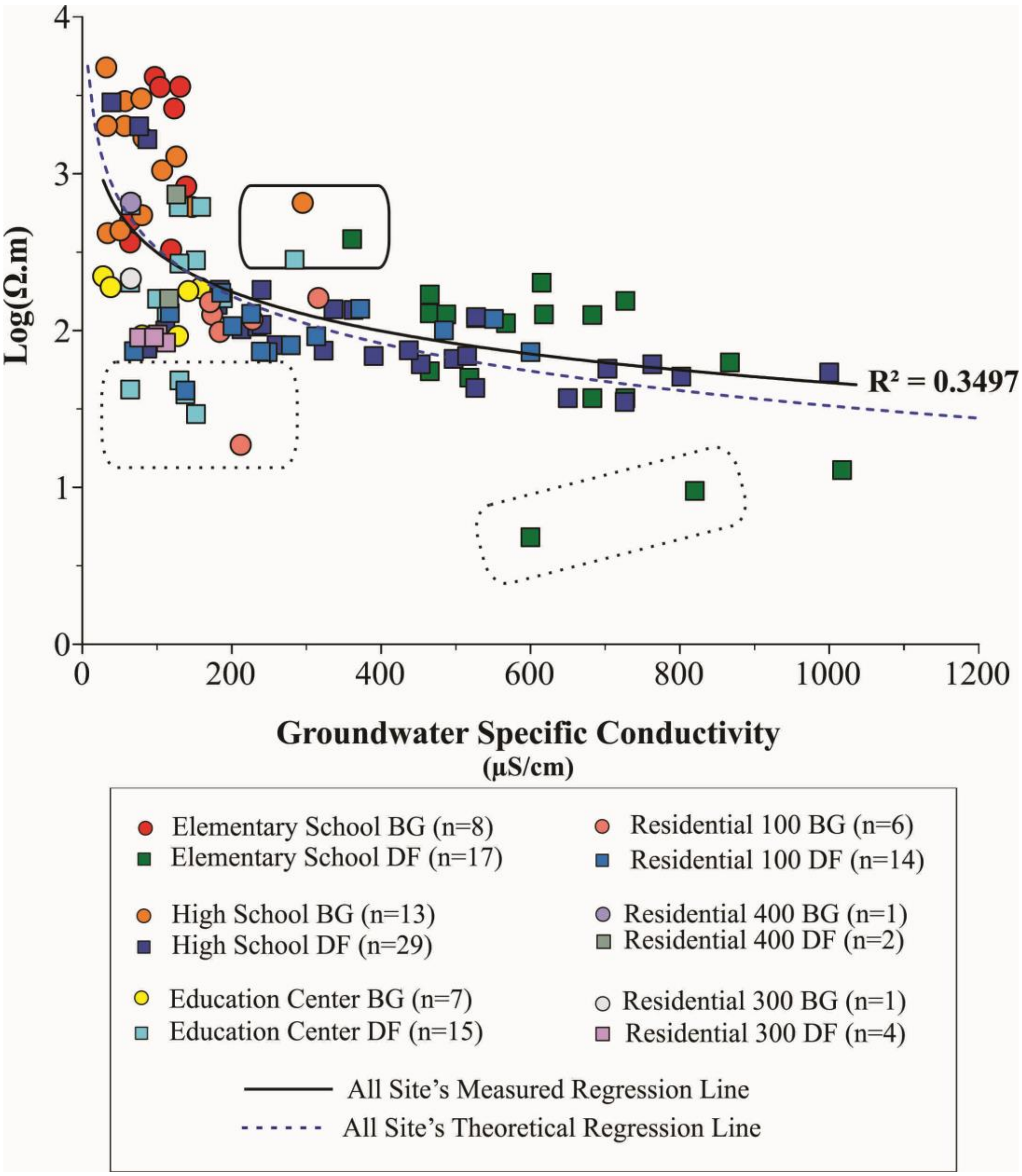
In Appendix Figure Q1, the drainfield resistivity (Ω.m) boxplot outliers all exceeded 250 Ω.m. The resistivity outliers ranged from 283-2852 Ω.m and had corresponding groundwater specific conductivity values that ranged from 39-372 μS/cm (Appendix Table G1 and Figure Q1). In Appendix Figure Q1, the highest drainfield resistivity outliers (>1,000 Ω.m) were collected from the high school and had low corresponding groundwater specific conductivity values (< 200 μS/cm). The pooled data set resistivity responses to changes in groundwater specific conductivity were assessed in Appendix Figure Q2. In Appendix Figure Q2 and Q3, the pooled data set had an inverse relationship between the Log (resistivity) and groundwater specific conductivity values.



Appendix Figure Q2. Scatter plot with a measured regression line (solid black) and R^2 value calculated using pooled background (BG; black circles) and drainfield (DF; red squares) CCR survey Log resistivity values (Ω.m) and groundwater specific conductivity (µS/cm) (Appendix Table F1). The theoretical regression line (purple line) The dot - dashed black line labeled 250 Ω.m is a reference line taken from Smith (2013) discussed in the Methods.

Most drainfield (squares) resistivity values were less than 250 Ω.m or $10^{2.398}$ Ω.m and corresponding drainfield groundwater specific conductivity values were greater than 200 µS/cm (Appendix Figure Q2). In Appendix Figure Q2 most background groundwater specific conductivity values (circles) were less than 200 µS/cm and approximately half of the resistivity values were greater than 250 Ω.m.

The theoretical regression analysis was completed using bulk resistivity and calculated pore water specific conductivity (dashed purple line, Appendix Figure Q2 and Q3). In Appendix Figures Q2 and Q3, the theoretical regression analysis (dashed purple line) showed a similar pattern to the measured regression analysis (solid black line). The regression analyses were characterized by similar resistivity changes associated with changes in groundwater specific conductivity collected from background and drainfield locations (Appendix Figure Q2 and Q3).



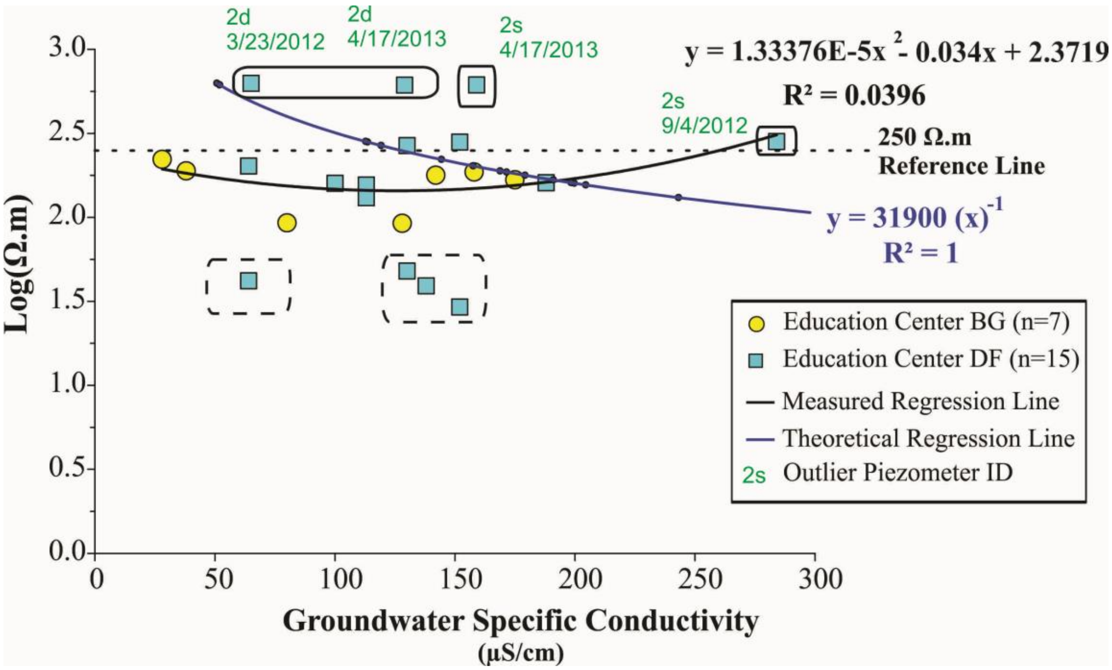
Appendix Figure Q3. Scatterplot of background (BG) and drainfield (DF) pooled Log resistivity vs groundwater specific conductivity. The dashed circle identifies major outliers less than 250 Ω.m. The solid circle identifies major outliers greater than 250 Ω.m. The values for outliers are organized and listed in Appendix Table G1.

In Appendix Figure Q3, the outliers that deviated from the regression curve were sourced from sites with small septic systems (the education center, Residential 100 and Residential 300) and 1 site with a large septic system (the elementary school).

Objective 1 Results: education center, Residential 100, 300 and 400

In Appendix Figures Q4-Q6, the 250 Ω.m reference line was used to draw attention to the similarity in resistivity and groundwater specific conductivity values across background and drainfield areas at the sites with smaller OWS. The 250 Ω.m reference line was helpful in constraining values possibly influenced by wastewater inputs at the schools by Smith (2013). In the current study, the reference line does not mark values that have or have not been influenced by wastewater inputs. The 250 Ω.m reference line was used to show the relationship and trends between values collected at the sites with small and large OWS. The R^2 values and scatter plot observations were discussed below for the sites with small OWS: education center and Residential 100 and supplemental Residential 300 and 400.

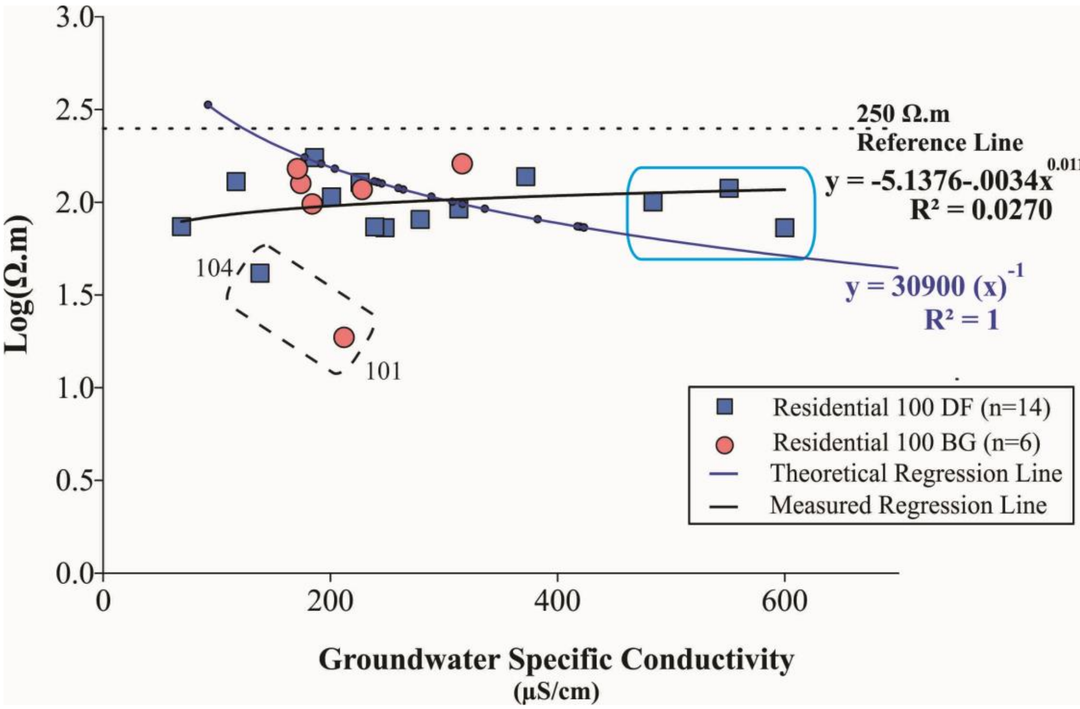
The majority of the education center resistivity values were less than 250 Ω.m and have corresponding groundwater specific conductivity values less than 200 µS/cm collectively across background and drainfield locations (Appendix Figure Q4). The average drainfield resistivity values during the current study were 243 ± 204.8 Ω.m and the median resistivity was 160.8 Ω.m (n=15). Elevated drainfield resististivity values that ranged from 614-628 Ω.m were identified on 3/23/2012 at piezometer 2d and 4/17/2013 at piezometer 2s and 2d (Appendix Figure Q4).



Appendix Figure Q4. Education center scatterplot of background (BG) and drainfield (DF) values resistivity (Ω.m) and specific conductivity (µS/cm) values. The measured regression line (solid black) and the theoretical regression line (solid purple) are provided. The R^2 value for the measured regression line is given in bold black and the theoretical regression equation and R^2 value are given in purple font. The solid line rectangle identifies resistivity values ≥250 Ω.m and the dashed line rectangle identifies resistivity values ≤250 Ω.m.

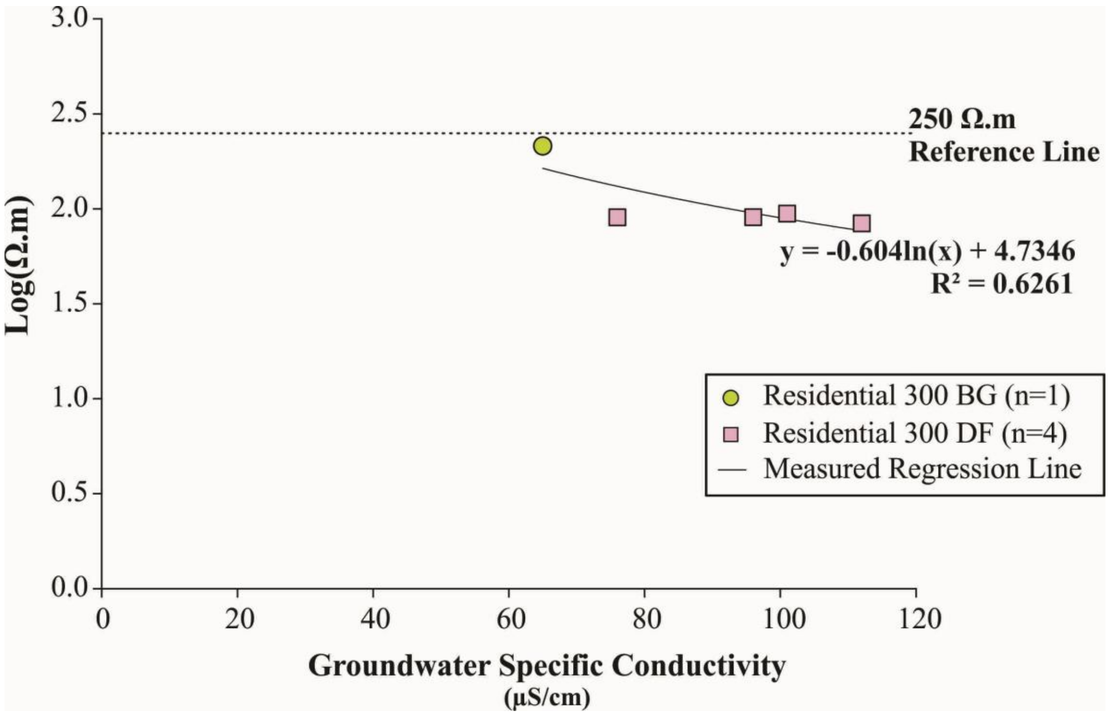
The outlier drainfield piezometers 2d (3/23/2012 and 4/17/2013) and 2s (4/17/2013) had resistivity values greater than 250 Ω.m and corresponding groundwater specific conductivity values all less than 200 µS/cm (Appendix Figure Q2, solid line rectangle). Piezometer 2s on 9/14/2012 had a resistivity value greater than 250 Ω.m and groundwater specific conductivity value greater than 200 µS/cm (Appendix Figure Q4, solid line rectangle). Drainfield piezometers 3 (3/23/2012, 11/29/2012 and 4/17/2013) and 2s (11/29/2012) had resistivity values less than 250 Ω.m and groundwater specific conductivity values less than 200 µS/cm (Appendix Figure Q4, dashed rectangle). The drainfield groundwater specific conductivity values (n=11) never exceeded 200 µS/cm except on 9/4/2012 piezometer 2s (284 µS/cm).

All of the Residential 100 drainfield (squares) and background (circles) resistivity values were less than 250 Ω.m (Appendix Figure Q5). In Appendix Figure Q5, the corresponding background and drainfield groundwater specific conductivity values range from 69 µS/cm to 372 µS/cm excluding values collected from piezometer 110s in which the groundwater specific conductivity values were ≥ 400 µS/cm (solid blue circle).



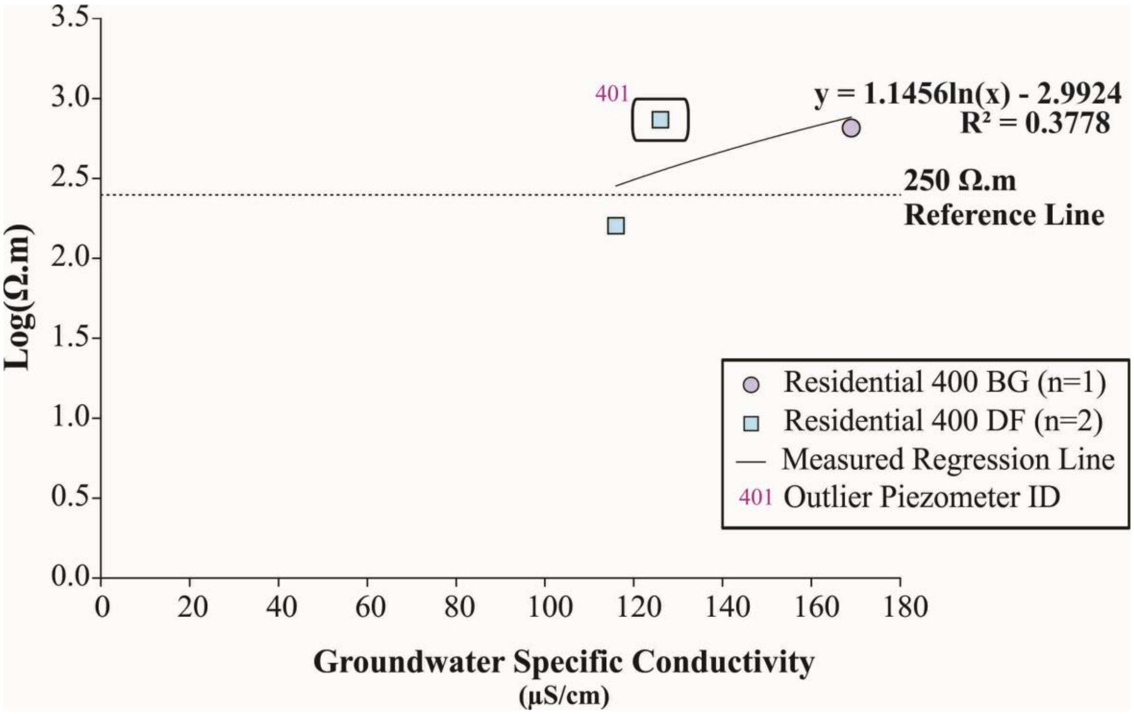
Appendix Figure Q5. Shows the Residential 100 scatterplot of background (BG) and drainfield (DF) resistivity (Ω.m) and specific conductivity (µS/cm) values. The measured regression line (solid black) and the theoretical regression line (solid purple) are provided; the R^2 value for the measured regression line is given in bold black. The theoretical regression equation and R^2 value are given in purple font. The dashed line rectangle identifies resistivity values ≤250 Ω.m and the solid light blue line rectangle identifies outlier drainfield piezometers that are believed to show wastewater influence. Regression formulas are listed in Appendix Table Q1.

In Appendix Figure Q5, the dashed circle marks outlier piezometers 101 and 104 that have resistivity values less than 250 Ω.m and corresponding groundwater specific conductivity values equal to 174 and 138 µS/cm respectively (< 200 µS/cm) (Table 4).



Appendix Figure Q6. Scatterplot shows BG (circle) and DF (square) specific conductivity (µS/cm) and Log resistivity (Ω.m) values collected from Residential 300 on 9/7/2012 (Appendices Table F1). A black, dashed reference line is set at 250 Ω.m and labeled. The regression line is labeled with a corresponding equation and R^2 value.

The Residential 300 background and drainfield resistivity values were all less than 250 Ω.m (Appendix Figure Q6). All groundwater specific conductivity values were less than 200 µS/cm (Appendix Figure Q6). The R^2 value at Residential 300 was 0.6261 (Appendix Figure Q6).



Appendix Figure Q7. Scatterplot shows BG (circle) and DF (square) specific conductivity (µS/cm) and Log resistivity (Ω.m) values collected from Residential 400 on 9/7/2012 (Appendices Table F1). A black, dashed reference line is set at 250 Ω.m and labeled. The regression line is labeled with a corresponding equation and R^2 value. The solid circle identifies the one drainfield outlier with a resistivity > 250 Ω.m at Residential 400 (Appendices Table G1)

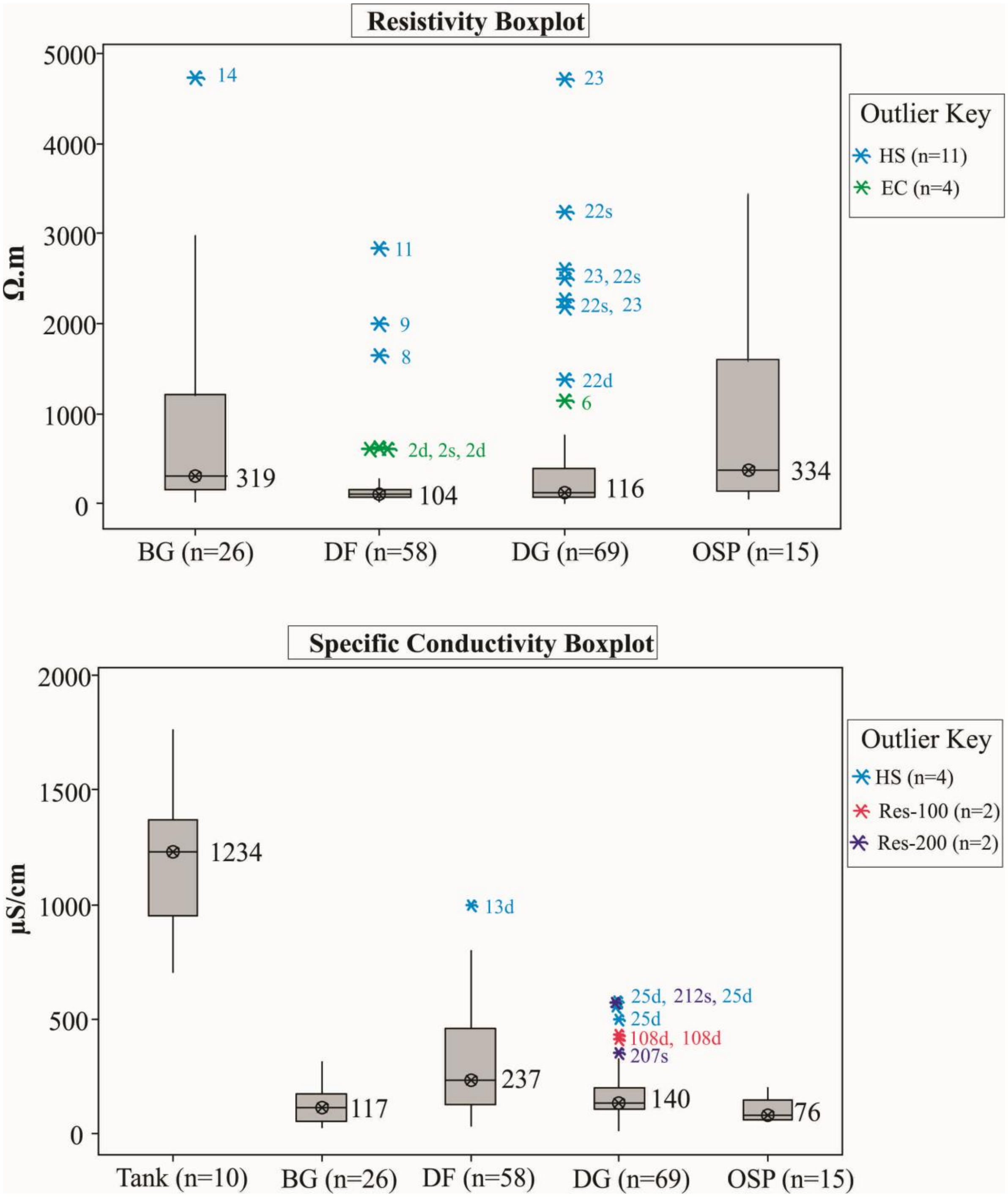
The Residential 400 two drainfield resistivity values were 737 Ω.m and 160 Ω.m. and the corresponding groundwater specific conductivity values for both the drainfield and background piezometers were ≤ 200 µS/cm. The R^2 = 0.3778 at Residential 400 (Appendix Figure 7). The Mann-Whitney comparisons of the combined Residential 300 and 400 dataset were provided in Table 4.

Appendix R: Objective 2 Additional Results and Discussion

The high school was selected as the main study site due to the number of downgradient piezometers installed at the site. Initially, downgradient values were assessed for the pooled data set and at individual sites: education center Residential 100 and Residential 200.

Objective 2 Results: Pooled Dataset

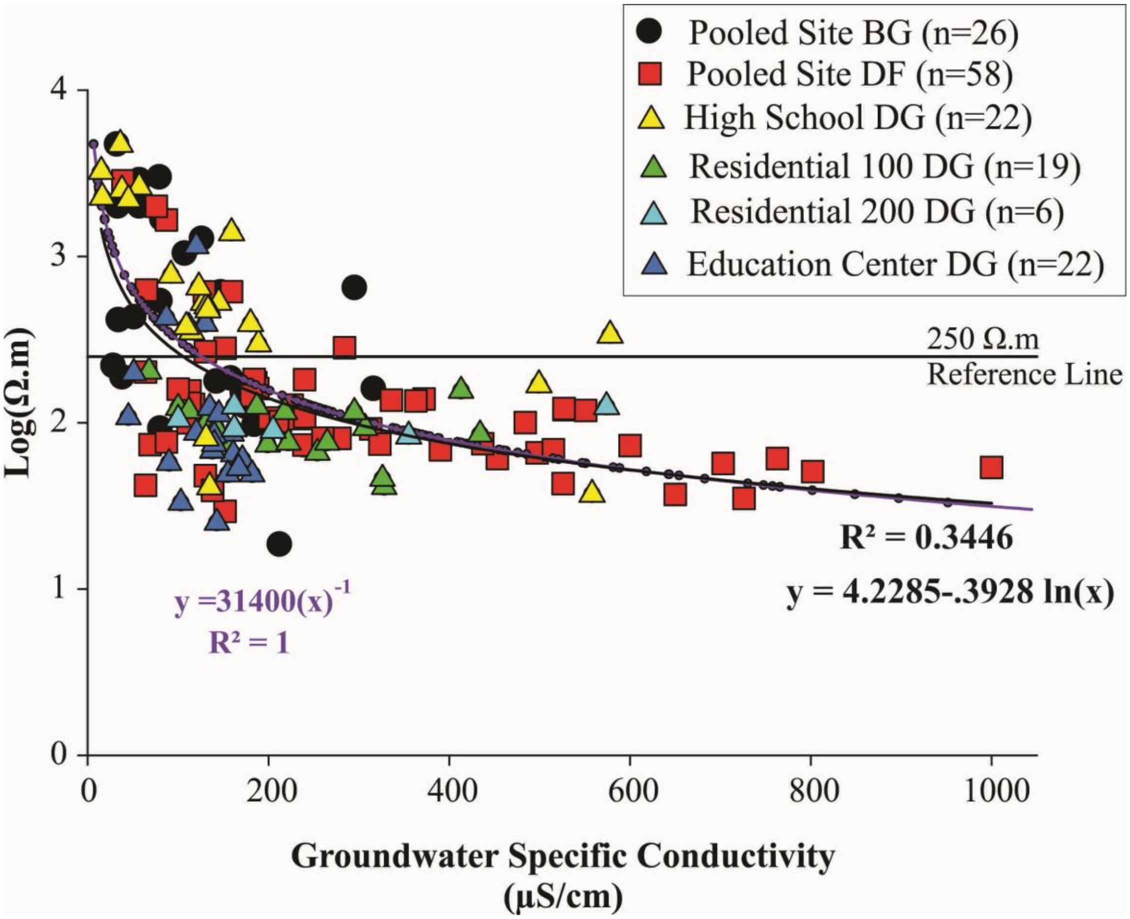
The pooled data sites consisted of the high school, education center, and Residential 100 and 200. The median contrast between the background and downgradient groundwater specific conductivity was 23 µS/cm. In Appendix Figure R1, the resistivity, downgradient median was greater than the background median and less than the drainfield median. In Appendix Figure R1, the downgradient median groundwater specific conductivity was greater than the background median and less than the drainfield median.



Appendix Figure R1. Boxplots show pooled resistivity (Ω.m) and groundwater specific conductivity (µS/cm) values collected from background (BG), drainfield (DF), and downgradient of the drainfield (DG) locations and areas outside of the OWS plume (OSP) (Appendix Table F2). The outliers are color coded and values were listed in Appendix G2. The numbers located adjacent to median line and symbol were median values. OSP values were assessed in Appendix F3.

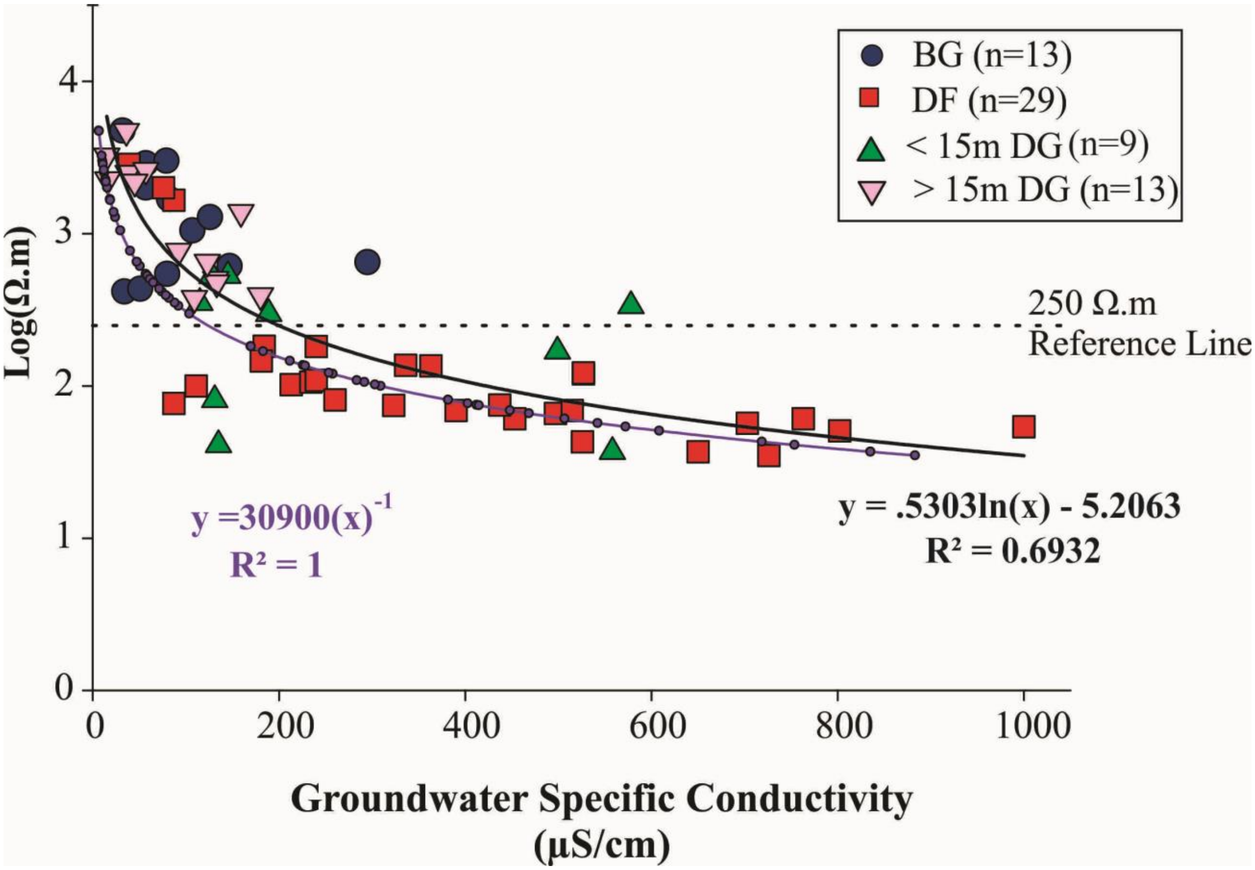
In Appendix Figure R1, all of the resistivity downgradient outliers (n=8) were ≥ 1,000 Ω.m and collected greater than 15 m from the drainfield (Appendix Table G2). The high school outliers (n=7) had resistivity values that ranged from 1388-4718 Ω.m (≥ 250 Ω.m) and corresponding groundwater specific conductivity values that ranged from 15-159 µS/cm (≤ 200 µS/cm) (Appendix Figure R1 and Appendix Table G2). The remaining downgradient resistivity outlier was collected from the education center. The education center resistivity outlier was 1155 Ω.m and the corresponding groundwater specific conductivity value was 120 µS/cm (Appendix Figure R1 and Appendix Table G2).

In the Appendix Figure R1, the downgradient, groundwater specific conductivity boxplot outlier values ranged from 355-578 µS/cm (≥ 200 µS/cm) and had corresponding resistivity values that ranged from 15-169 Ω.m (≤ 250 Ω.m). Three of the elevated downgradient groundwater specific conductivity values were collected from the high school piezometer 25d.

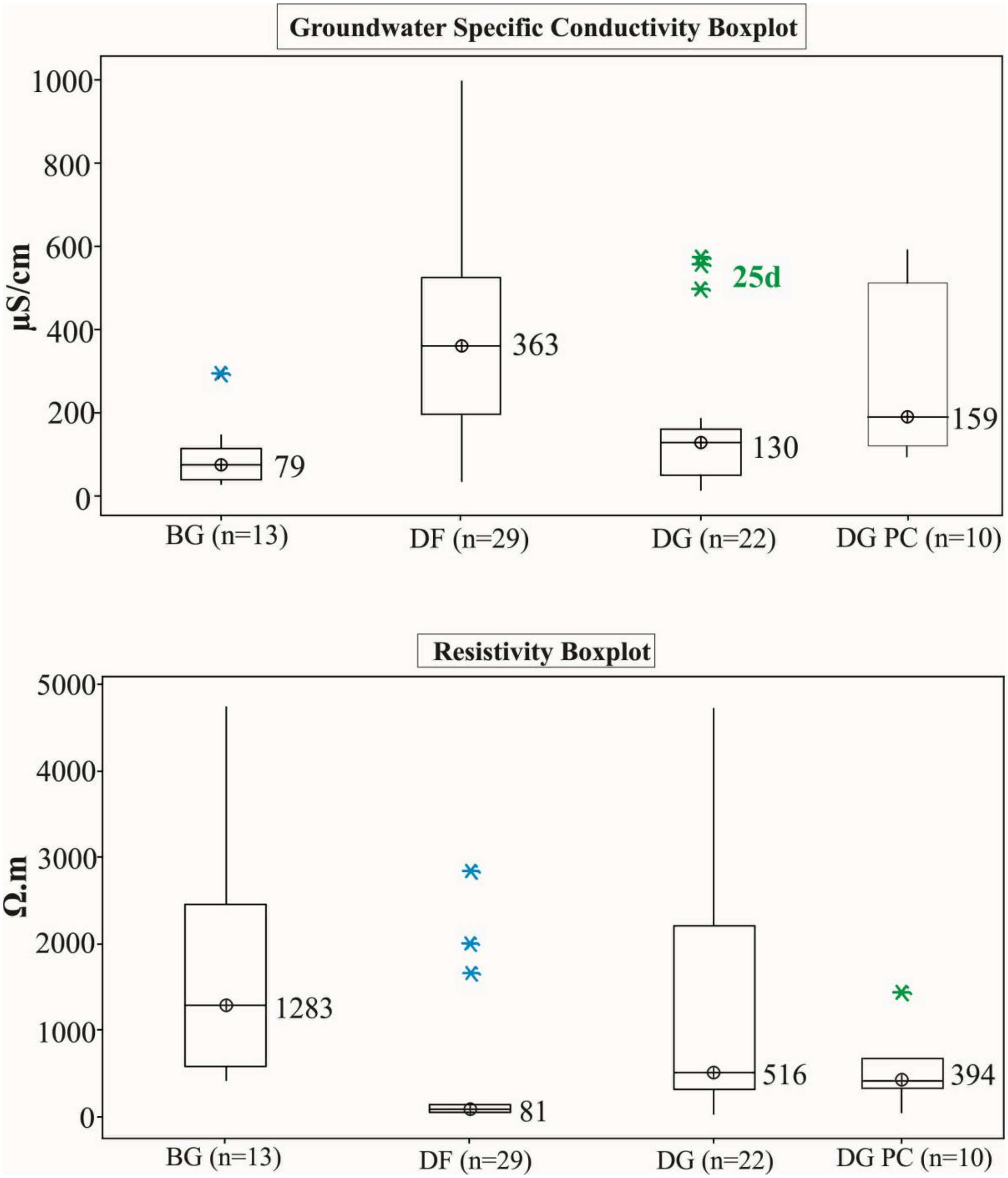


Appendix Figure R2, shows background, drainfield and downgradient Log resistivity vs groundwater specific conductivity values along with a labeled reference line and regression line (black). The purple equation, R^2 value and line represent the theoretical regression analysis between bulk resistivity (y) and pore water specific conductivity (x).

Objective 2 Results: High School



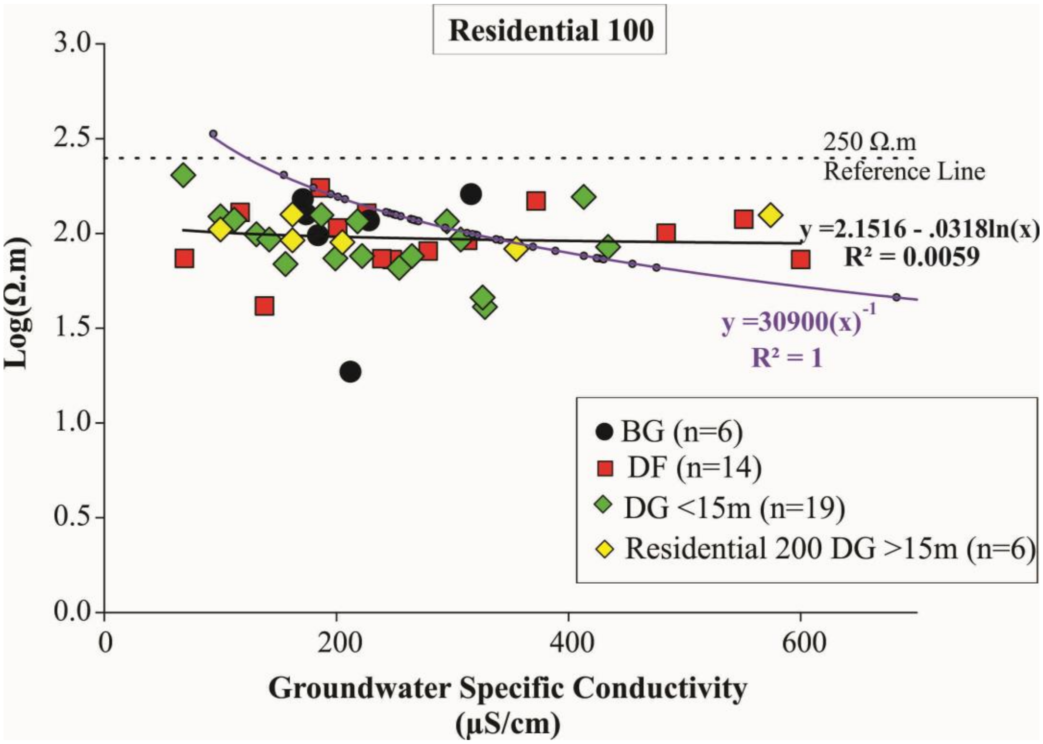
Appendix Figure R3 shows background, drainfield and downgradient Log resistivity vs groundwater specific conductivity values collected from the high school along with a labeled reference line (dashed black line) and a measured regression line (solid curved line). The downgradient values are divided based on the location of the piezometer less than or greater than 15 m from the drainfield. The purple equation, R^2 value and line represent the theoretical regression analysis between bulk resistivity (y) and pore water specific conductivity (x).



Appendix Figure R4. High school boxplots of background (BG), drainfield (DF), downgradient (DF) and downgradient plume core (DG PC) groundwater specific conductivity (µS/cm) and resistivity (Ω.m). The plume core had groundwater specific conductivity > 124 µS/cm (Appendix Table F2). Downgradient piezometer 25d was located with the wastewater plume core.

Objective 2 Results: Residential 100, 200 and education center

All of the downgradient values for both Residential 100 and Residential 200 were less than 250 Ω.m and the majority of the corresponding groundwater specific conductivity values were less than 400 µS/cm (Appendix Figure R5). The Residential 100 downgradient resistivity values range from 41-203 Ω.m and corresponding groundwater specific conductivity values range from 68-434 µS/cm (Appendix Figure R5). The R^2 value for the Residential 100 Log resistivit vs groundater specific conductivyt values was 0.0059 (Appendix Figure R5 and Table 5).



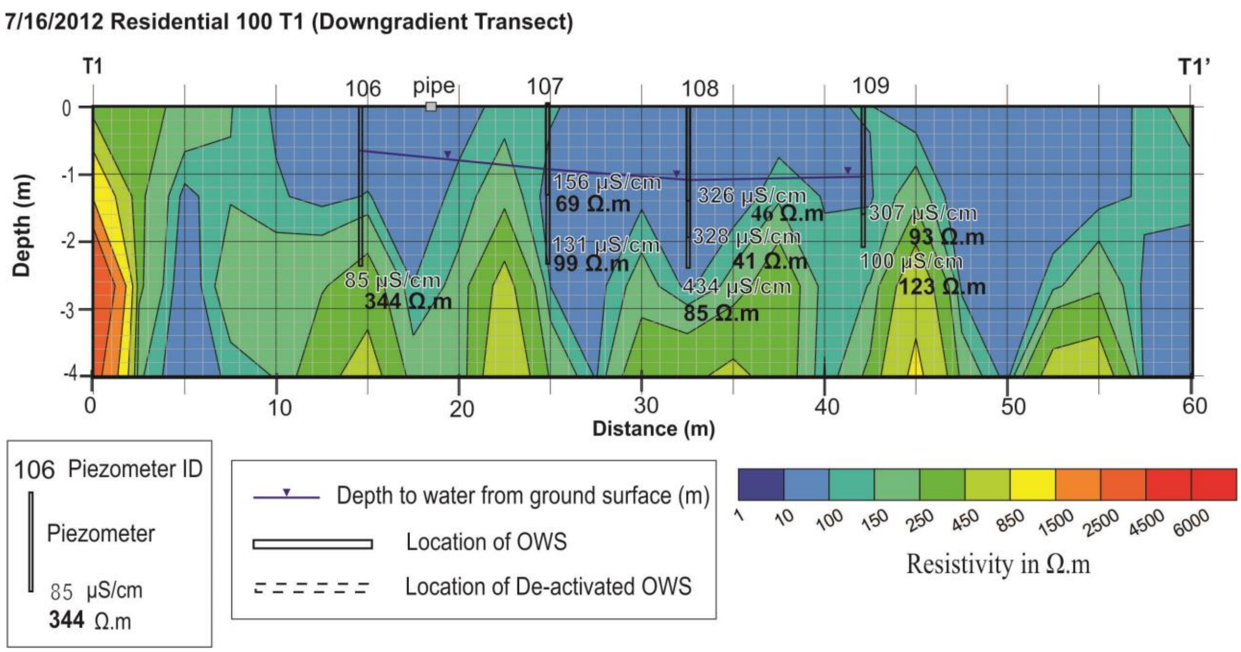
Appendix Figure R5. The Residential 100 scatter plot of all the background (BG; circle), drainfield (DF; squares), and downgradient (DG; diamonds) Log resistivity (Ω.m) and groundwater specific conductivity (µS/cm) values collected from Residential 100 and 200. The background, drainfield, and downgradient values were listed in Appendix Table F2. Note that at Residential 200 there was only 1 survey date and no background or drainfield values were collected. The purple equation, R^2 value and line represent the regression analysis between bulk resistivity (y) and pore water specific conductivity (x).

Residential 200 was not a main focus area and provided only supplemental data for the regression analysis. Residential 200 data were not collected from background or drainfield piezometers so no comparisons were completed for the Residential 200 downgradient data. The Residential 200 downgradient piezometers were located ≥ 25 m from the Residential 100 drainfield with a stream seperating the two sites (Appendix Figure H5). The Residential 200 downgradient resistivity values range from 83-126 Ω.m and corresponding groundwater specific conductivity values range from 100-574 µS/cm (Appendix Figure R5).

To view the lateral behavior of resistivity values at Residential 100 across background, drainfield and downgradient areas a slice of a 3D CCR sruvey was overlayed onto the Residential 100 map (Appendix Figure R6).

Appendix Figure R6. A resistivity 3D survey collected at 0.5 mbgs on 7/16/2012 at Residential 100 (purple square) and the approximate location of the active OWS (solid black box) and the de-activated OWS (dashed black box). The blue arrow marks the direction of groundwater flow. All of the resistivity values shown on the survey slice at 0.5 mbgs were less than 250 Ω.

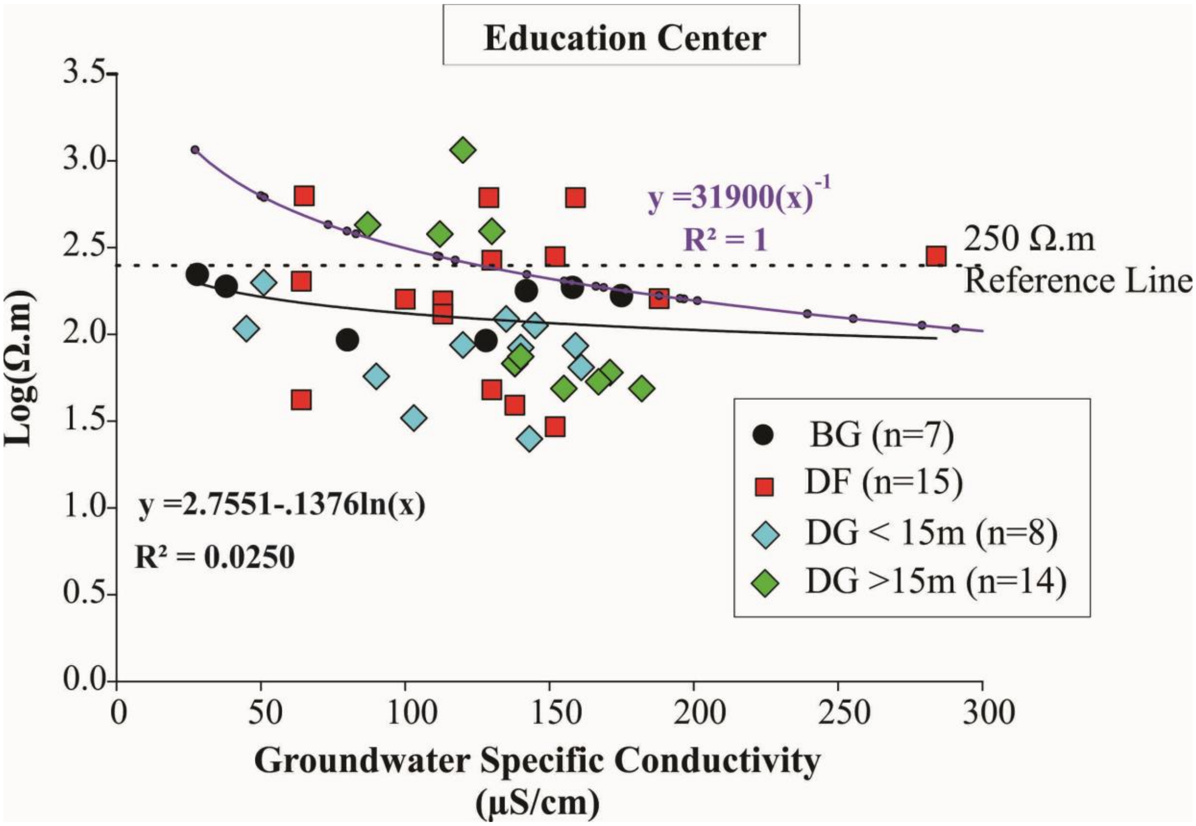
The 3D surveys conducted at Residential 100 did not cover downgradient piezometers, due to the trees and a shed at the site that prevented the extension of the survey area (Appendix Figure R6). In Appendix Figure R6, the 3D survey shows that background piezometers (101 and 102), drainfield piezometers (104, 110, 105), and downgradient areas had resistivity values that ranged from 63-250 Ω.m. The resistivity values in the active drainfield and downgradient areas range from 63-110 Ω.m (Appendix Figure R6). The Residential 100 Transect 1 was collected downgradient of the drainfield to obtain resistivity values for the downgradient piezometers 107-109 (Appendix Figure R7).



Appendix Figure R7. Residential 100 T1 collected on 7/16/2012. The transect was located approximately 14 m downgradient of the active OWS drainfield (Appendix Figure H4). The resistivity values of piezometers within the flow path (piezometers: 107-109) ranged from 41-123 Ω.m and groundwater specific conductivity values ranged from 131-434 µS/cm.

The Residential 100, nested piezometers: 107, 108, 109, were located downgradient of the OWS drainfield (Appendix Figure R7). In Appendix Figure R7, the lowest resistivity values (≥ 250 Ω.m) and higher groundwater specific conductivity values (≤ 200 µS/cm) were collected from the centrally located downgradient piezometer 108. Piezometer 106 was not within the calculated flow path and is labeled as OSP (Appendix F3). In Appendix Figure R7 the piezometer 106 had the highest resistivity value of 344 Ω.m and the lowest groundwater specific conductivity value of 85 µS/cm of all piezometers located downgradient of the OWS drainfield.

The education center, downgradient resistivity values for piezometers ranged from 25-1155 Ω.m and corresponding groundwater specific conductivity values ranged from 28-284 µS/cm (Appendix Table F2). All downgradient values collected from piezometers located less than 15 m from the drainfield had groundwater specific conductivity values less than 200 µS/cm and corresponding resistivity values less than 250 Ω.m (Appendix Figure R8). The contrast between the median background and $\leq$ 15 m from the drainfield groundwater specific conductivivity valeus was 2 µS/cm.

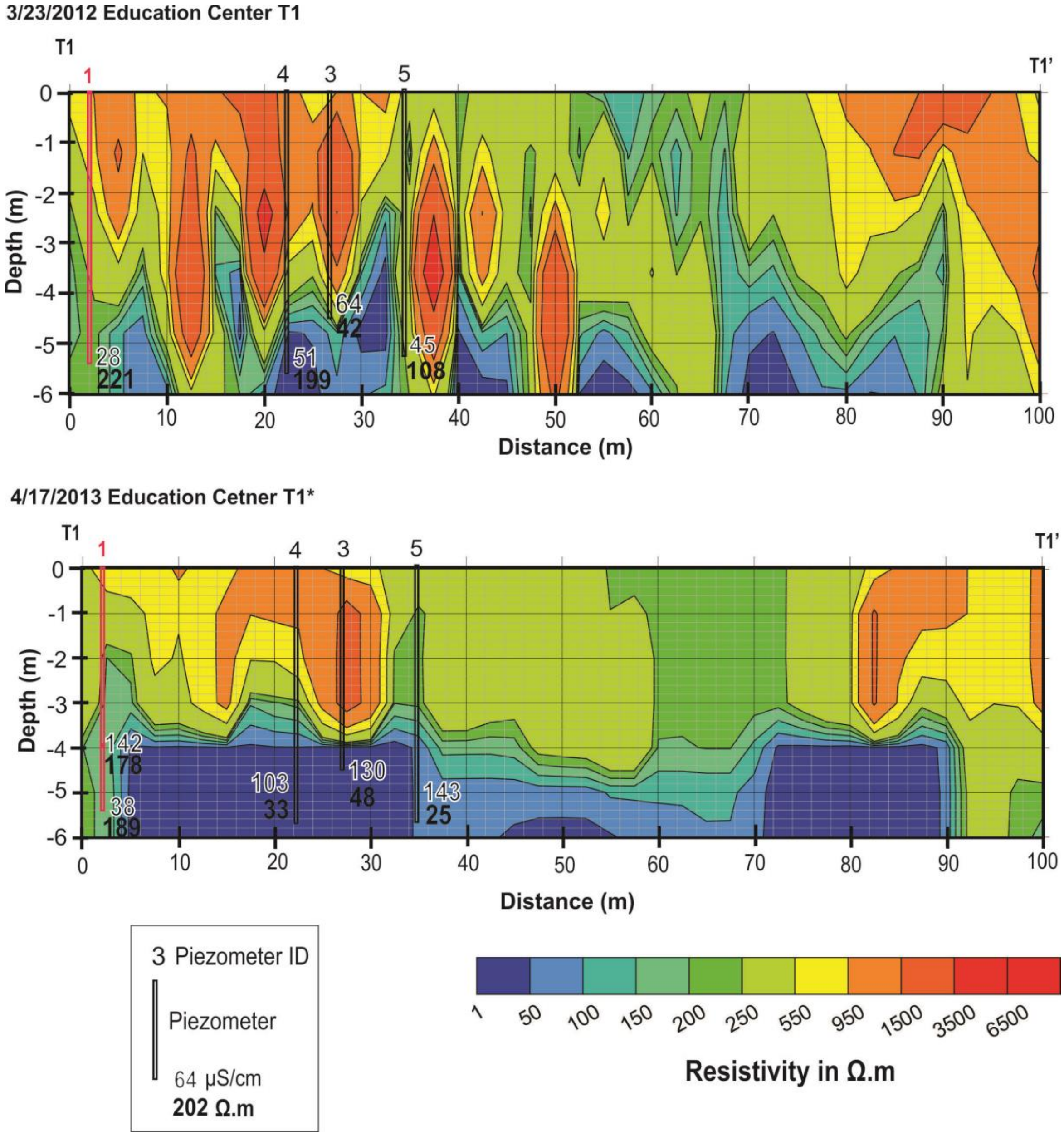


Appendix Figure R8. Education center scatter plot of background (BG), drainfield (DF), and downgradient (DG) Log resistivity (Ω.m) values vs groundwater specific conductivity (µS/cm) values. The measured regression equation and R^2 value are shown in black bold font; along with the measured regression curved line in black. A dashed black reference line is set at 250 Ω.m. The background, drainfield, and downgradient values are listed in Appendix Table F2. The purple equation, R^2 value and line represent the theoretical regression analysis between bulk resistivity (y) and pore water specific conductivity (x).

The downgradient piezometers located greater than 15 m downgradient of the drainfield have resistivity values that ranged from 38-1155 Ω.m and corresponding groundwater specific conductivity values that ranged from 90-182 µS/cm (Appendix Figure R8).

The Mann-Whitney comparisons of downgradient resistivity and groundwater specific conductivity data sets in Table 5 had p-values < 0.05; except for the resistivity comparison of drainfield data sets with ≤ 15 downgradient of the drainfield data sets in which the p-value was 0.0490. Downgradient piezometers located less than 15 m downgradient from the drainfield consisted of piezoemter 4 and 5. The dowgradient piezometer 4 groundwater specific conductivity average and meidan values were 102 ± 32.7 µS/cm and 111.5 µS/cm (n=4) respectivly. The downgradient piezometer 5 groundwater sepcific condcutivity average and median values were 82.9 ± 45.5 µS/cm and 123 µS/cm (n=4) respectivly.

The ≤ 15 downgradient of the drainfield resistivity median was 98 Ω.m and the drainfield median was 161 Ω.m (Table 5). The contrast between the data sets may be attributed to interference resulting from the presence of lower resistivity sediments near the downgradient piezometers screened interval (Appendix Figure R9). On all survey dates a low resistivity values were present at the piezometer 4 and 5 screened interval at approximately 4 mbgs (Appendix Figure R9 and Figure 13). The low resistivity area was characterized by groundwater specific conductivity values collected from piezometer 4 and 5 and ranged from 45-159 µS/cm (< 200 µS/cm). CCR Transect 1 was collected downgradient of the drainfield on the first and last survey dates (Appendix Figure R9). The downgradient piezometers 4 and 5 were located < 5 m from the Transect 1 and were installed at depths accessing the low resistivity areas shown in Appendix Figure R9. In Appendix Figure R9, the resistivity values for the dowgradient piezometers 4 and 5 ranged from 25-199 Ω.m (<250 Ω.m) and correpsonding groundwater speicific conductivity ranged from 45-143 µS/cm (< 200 µS/cm).



Appendix Figure R9 Shows T1 collected on 3/23/2012 and 4/17/2013 (Appendix Figure H3). The * after the T1 4/17/2013 title is a reminder that the transect was collected with 10 m long dipoles instead of 5 m long dipoles indicating the 4/17/2013 transect resistivity values were averaged over a larger area. The piezometer in red marks the location selected for the background piezometer 1. The piezometers 4 and 5 were downgraident piezometers. Piezometer 3 was located within the drainfield approximatley 5 m Transect 1.

Additionally, the downgradient TDN average at peizometer 4 was 2.48 ± 0.95 mg/L and at piezometer 5 was 6.91 ± 0.44 mg/L. Piezometer 5 did have a slightly elevated TDN value relative to the education center drainfield 2s 6.01 ± 1.36 mg/L. The drainfield piezometer 2s was centrally located, near the front of the drainfield. The similarity between the averages for piezometer 5 and 2s may support the wastewater influence at both peizometers that was not detected with the CCR resistivity results or groundwater sepcific conductivity.

Appendix S: Skin Depth

Skin depth was used to determine the maximum transmitter-receiver separation distance and is controlled by the AC signal (approximately 16.5 kHz), and the resistivity of the environment (Geometrics, 2001). Equation S1 was used to calculate skin depth in meters (Geometrics, 2001).

$$500 * \sqrt{\frac{\rho}{f}} \qquad \text{(Eq. S1)}$$

Where ρ = resistivity (Ω.m) and f = transmitter frequency in hertz (16500 hertz). If the distance from the transmitter to the receiver exceeds the calculated skin depth (maximum distance) the signal will not be detected by the receiver (Geometrics, 2001). A resistivity value equal to 250 Ω.m has a skin depth of 62 m. Resistivity values less than 250 Ω.m would have skin depths less than 62 m. The skin depths were calculated at each site using the resistivity values collected from drainfield areas where the wastewater inputs were expected to be highest and the resistivity values the lowest, except at Residential 200. Collectively, at all sites, the longest nonconductive tow link cable length used was 20 m. Skin depth was not a limiting factor in the current study. The focus area investigation depth was 7 m and less depending on the sites. The maximum resistivity survey depth achieved using the 20 m nonconductive tow link cable was approximately 9.5 mbgs.

Appendix T: Archie's Law

Table T1: Shows the µS/cm (groundwater specific conductivity) and resistivity values collected via water quality analysis and from CCR surveys, respectively (below). The table also shows the calculated pore water resistivity (p_w) and calculated pore water µS/cm (specific conductivity). The values were calculated using the Appendix L2 formation factors and equations 6-9. In the charts below the calculated pore water resistivity and calculated pore water specific conductivity values were only estimated for the values collected from background and drainfield piezometers at the focus study sites: high school (HS), elementary school (ES), education center (EC), and Residential 100.

High School (Site: HS)

Site	Date Sampled	Transect ID	Piezometer ID	µS/cm	Ω.m Selected at Screened Interval	Log (Ω.m)	Calculated Ω.m (p_w)	Log Ω.m (p_w)	Calculated pore water µS/cm	Location of Piezometer
HS	4/10/2012	T1	7	33	2012	3.3	651.1	2.8	15.36	BG
HS	9/7/2012	T1	7	57	2893	3.5	936.2	3.0	10.68	BG
HS	11/14/2012	T1	7	79	3006	3.5	972.8	3.0	10.28	BG
HS	4/10/2012	T1	1d	82	1684	3.2	545.0	2.7	18.35	BG
HS	9/7/2012	T1	1d	107	1048	3.0	339.2	2.5	29.48	BG
HS	4/10/2012	T1	1s	295	650	2.8	210.4	2.3	47.54	BG
HS	9/7/2012	T1	1s	126	1283	3.1	415.2	2.6	24.08	BG
HS	11/14/2012	T1	1s	147	612	2.8	198.1	2.3	50.49	BG
HS	9/7/2012	T2	2	80	543	2.7	175.7	2.2	56.91	BG
HS	9/7/2012	T2	3	34	417	2.6	135.0	2.1	74.10	BG
HS	9/7/2012	T2	5	51	434	2.6	140.5	2.1	71.20	BG
HS	9/7/2012	T3	14	32	4747	3.7	1536.2	3.2	6.51	BG
HS	9/7/2012	T3	7	57	2009	3.3	650.2	2.8	15.38	BG
HS	4/10/2012	T1	8	111	100	2.0	32.4	1.5	309.00	DF
HS	9/7/2012	T1	8	87	77	1.9	24.8	1.4	402.50	DF
HS	11/14/2012	T1	8	213	102	2.0	33.0	1.5	302.94	DF
HS	4/10/2012	T1	12	497	66	1.8	21.4	1.3	468.18	DF
HS	9/7/2012	T1	12	336	137	2.1	44.3	1.6	225.55	DF
HS	11/14/2012	T1	12	234	106	2.0	34.3	1.5	291.51	DF
HS	4/10/2012	T1	18	515	69	1.8	22.3	1.3	447.83	DF
HS	9/7/2012	T1	18	184	183	2.3	59.1	1.8	169.31	DF
HS	11/14/2012	T1	18	390	69	1.8	22.3	1.3	447.83	DF

HS	4/10/2012	T1	13d	1000	54	1.7	17.5	1.2	572.22	DF
HS	9/7/2012	T1	13d	802	51	1.7	16.4	1.2	608.27	DF
HS	11/14/2012	T1	13d	726	35	1.5	11.3	1.1	882.86	DF
HS	4/10/2012	T1	13s	763	61	1.8	19.7	1.3	506.56	DF
HS	9/7/2012	T1	13s	363	136	2.1	43.9	1.6	227.88	DF
HS	11/14/2012	T1	13s	453	61	1.8	19.7	1.3	506.56	DF
HS	9/7/2012	T4	24D	527	120	2.1	38.8	1.6	257.50	DF
HS	9/7/2012	T4	24S	240	109	2.0	35.3	1.5	283.49	DF
HS	4/10/2012	T1	15	703	57	1.8	18.4	1.3	542.11	DF
HS	9/7/2012	T1	15	181	146	2.2	47.2	1.7	211.64	DF
HS	11/14/2012	T1	15	260	81	1.9	26.2	1.4	381.48	DF
HS	4/10/2012	T1	24D	650	37	1.6	12.0	1.1	835.14	DF
HS	9/7/2012	T1	24D	527	122	2.1	39.5	1.6	253.28	DF
HS	11/14/2012	T1	24D	437	75	1.9	24.3	1.4	412.00	DF
HS	4/10/2012	T1	24S	526	43	1.6	13.9	1.1	718.60	DF
HS	9/7/2012	T1	24S	240	182	2.3	58.9	1.8	169.78	DF
HS	11/14/2012	T1	24S	323	75	1.9	24.1	1.4	414.38	DF
HS	9/7/2012	T6	11	39	2852	3.5	923.0	3.0	10.83	DF
HS	9/7/2012	T6	8	87	1659	3.2	536.9	2.7	18.63	DF
HS	9/7/2012	T2	9	76	2007	3.3	649.5	2.8	15.40	DF

Elementary School (Site: ES)

Site	Date Sampled	Transect ID	Piezometer ID	µS/cm	Ω.m Selected at Screened Interval	Log (Ω.m)	Calculated Ω.m (p_w)	Log Ω.m (p_w)	Calculated pore water µS/cm	Location of Piezometer
ES	9/10/2012	T1	2	97	4121	3.6	1212.1	3.1	8.25	BG
ES	11/19/2012	T1	2	104	3564	3.6	1048.2	3.0	9.54	BG
ES	3/25/2013	T1	2	123	2601	3.4	765.0	2.9	13.07	BG
ES	9/10/2012	T1	3	139	827	2.9	243.2	2.4	41.11	BG
ES	11/19/2012	T1	3	131	3577	3.6	1052.1	3.0	9.51	BG
ES	3/25/2013	T1	3	119	327	2.5	96.2	2.0	103.98	BG
ES	9/10/2012	T3	9	64	498	2.7	146.5	2.2	68.27	BG
ES	9/10/2012	T5	9	64	364	2.6	107.1	2.0	93.41	BG
ES	9/10/2012	T1	10	597	4	0.64	1.3	0.1	7870.37	DF
ES	11/19/2012	T1	10	567	111.57	2.0	32.8	1.5	304.74	DF
ES	3/25/2013	T1	10	867	62.63	1.8	18.4	1.3	542.87	DF
ES	9/10/2012	T1	4	465	129	2.1	37.9	1.6	263.57	DF
ES	11/19/2012	T1	4	361	383	2.6	112.6	2.1	88.77	DF
ES	3/25/2013	T1	4	745	193	2.3	56.8	1.8	176.17	DF
ES	9/10/2012	T1	13d	683	37	1.6	10.9	1.0	918.92	DF
ES	11/19/2012	T1	13d	518	50	1.7	14.7	1.2	680.00	DF
ES	3/25/2013	T1	13d	487	127	2.1	37.4	1.6	267.72	DF
ES	9/10/2012	T1	13s	727	37	1.6	10.9	1.0	918.92	DF
ES	11/19/2012	T1	13s	465	50	1.7	14.7	1.2	680.00	DF
ES	3/25/2013	T1	13s	618	127	2.1	37.4	1.6	267.72	DF
ES	9/10/2012	T2	6	698	151	2.2	44.4	1.6	225.17	DF
ES	9/10/2012	T2	7	1036	14	1.1	4.1	0.6	2428.57	DF

ES	9/10/2012	T2	14	838	8	0.90	2.4	0.4	4250.00	DF
ES	9/10/2012	T6	4	465	170	2.2	50.0	1.7	200.00	DF
ES	9/10/2012	T6	5	615	202	2.3	59.4	1.8	168.32	DF
ES	9/10/2012	T1	2	97	4121	3.6	1212.1	3.1	8.25	BG
ES	11/19/2012	T1	2	104	3564	3.6	1048.2	3.0	9.54	BG
ES	3/25/2013	T1	2	123	2601	3.4	765.0	2.9	13.07	BG
ES	9/10/2012	T1	3	139	827	2.9	243.2	2.4	41.11	BG
ES	11/19/2012	T1	3	131	3577	3.6	1052.1	3.0	9.51	BG
ES	3/25/2013	T1	3	119	327	2.5	96.2	2.0	103.98	BG
ES	9/10/2012	T3	9	64	498	2.7	146.5	2.2	68.27	BG
ES	9/10/2012	T5	9	64	364	2.6	107.1	2.0	93.41	BG

Education Center (Site: EC)

Site	Date Sampled	Transect ID	Piezometer ID	µS/cm	Ω.m Selected at Screened Interval	Log (Ω.m)	Calculated Ω.m (p_w)	Log Ω.m (p_w)	Calculated pore water µS/cm	Location of Piezometer
EC	3/23/2012	T1	1D	28	221	2.3	69.3	1.8	144.34	BG
EC	9/4/2012	T1	1D	175	167	2.2	52.4	1.7	191.02	BG
EC	11/29/2012	T1	1D	80	92.7	2.0	29.1	1.5	344.12	BG
EC	4/17/2013	T1	1D	38	189	2.3	59.2	1.8	168.78	BG
EC	9/4/2012	T1	1S	158	186	2.3	58.3	1.8	171.51	BG
EC	11/29/2012	T1	1S	128	92	2.0	28.8	1.5	346.74	BG
EC	4/17/2013	T1	1S	142	178	2.3	55.8	1.7	179.21	BG
EC	3/23/2012	T1	3	64	42	1.6	13.2	1.1	759.52	DF
EC	9/4/2012	T1	3	113	156	2.2	48.9	1.7	204.49	DF
EC	11/29/2012	T1	3	152	281	2.4	88.1	1.9	113.52	DF
EC	4/17/2013	T1	3	130	48	1.7	15.0	1.2	664.58	DF
EC	3/23/2012	T3	3	64	202.39	2.3	63.4	1.8	157.62	DF
EC	9/4/2012	T3	3	113	131.19	2.1	41.1	1.6	243.16	DF
EC	11/29/2012	T3	3	152	29.32	1.5	9.2	1.0	1087.99	DF
EC	4/17/2013	T3	3	130	267.65	2.4	83.9	1.9	119.19	DF
EC	3/23/2012	T3	2D	65	628.1	2.8	196.9	2.3	50.79	DF
EC	9/4/2012	T3	2D	100	159.72	2.2	50.1	1.7	199.72	DF
EC	11/29/2012	T3	2D	138	39.17	1.6	12.3	1.1	814.40	DF
EC	4/17/2013	T3	2D	129	614.06	2.8	192.5	2.3	51.95	DF
EC	9/4/2012	T3	2S	284	282.88	2.5	88.7	1.9	112.77	DF
EC	11/29/2012	T3	2S	188	160.81	2.2	50.4	1.7	198.37	DF
EC	4/17/2013	T3	2S	159	614.91	2.8	192.8	2.3	51.88	DF

Residential 100 (Site: Res-100)

Site	Date Sampled	Transect ID	Piezometer ID	µS/cm	Ω.m Selected at Screened Interval	Log (Ω.m)	Calculated Ω.m (p_w)	Log Ω.m (p_w)	Calculated pore water µS/cm	Location of Piezometer
Res-100	7/16/2012	T3	101	212	18.6	1.3	6.0	0.8	1661.29	BG
Res-100	11/16/2012	T3	101	174	126	2.1	40.8	1.6	245.24	BG
Res-100	3/27/2013	T3	101	228	117	2.1	37.9	1.6	264.10	BG
Res-100	7/16/2012	T3	102	171	151.5	2.2	49.0	1.7	203.96	BG
Res-100	11/16/2012	T3	102	316	161	2.2	52.1	1.7	191.93	BG
Res-100	3/27/2013	T3	102	184	97.7	2.0	31.6	1.5	316.27	BG
Res-100	7/16/2012	T2	103	248	73	1.9	23.6	1.4	423.29	DF
Res-100	11/16/2012	T2	103	201	106.94	2.0	34.6	1.5	288.95	DF
Res-100	3/27/2013	T2	103	186	174.29	2.2	56.4	1.8	177.29	DF
Res-100	7/16/2012	T2	104	226	128	2.1	41.4	1.6	241.41	DF
Res-100	11/16/2012	T2	104	138	41.45	1.6	13.4	1.1	745.48	DF
Res-100	3/27/2013	T2	104	279	80.77	1.9	26.1	1.4	382.57	DF
Res-100	7/16/2012	T2	105	313	92	2.0	29.8	1.5	335.87	DF
Res-100	3/27/2013	T2	105	239	73.61	1.9	23.8	1.4	419.78	DF
Res-100	7/16/2012	T2	110d	69	74	1.9	23.9	1.4	417.57	DF
Res-100	11/16/2012	T2	110d	372	137	2.1	42.3	1.6	236.60	DF
Res-100	3/27/2013	T2	110d	117	129.4	2.1	41.9	1.6	238.79	DF
Res-100	7/16/2012	T2	110s	600	73	1.9	23.6	1.4	423.29	DF
Res-100	11/16/2012	T2	110s	484	100.51	2.0	32.5	1.5	307.43	DF
Res-100	3/27/2013	T2	110s	551	118.89	2.1	38.5	1.6	259.90	DF

Appendix U: Darcy's Law and Groundwater Velocity

Appendix Table U1 and U2 show separate calculations using Darcy's Law to estimate groundwater discharge.

Appendix Table U1 shows discharge (Q) estimates for the focus area. The area (A) was determined by calculated the area on the transects in which the resistivity values were less than 250 Ω.m. The transects ID and collection dates are listed in the table as well as the figure number (if present). At the elementary school and high school the K values were averaged from the piezometers listed in the chart.

Discharge estimates calculated from CCR Surveys for Drainfield and Downgradient plumes										
Focus Area	**Piezometer**	**Transect Orientation Relative to GW Flow Direction**	**Q (m^3/yr)**	**Q (m^3/d)**	**K (m/d)**	**dh/dl**	**A (m^2)**	**CCR Transect ID**	**Date**	**Figure**
High School: DF	8, 12, 13, 15, 18, 24	parallel	1473	4.1	1.36	0.0064	470	T1	11/14/2012	17
High School: DF	24	perpendicular	51	0.1	1.11	0.0008	158	T4	9/7/2012	-
High School: DG	21	perpendicular	46	0.1	1.79	0.0006	120	T5	9/7/2002	-
Elementary School: DF	4, 6, 10, 13, 11	parallel	946	2.6	0.73	0.012	300	T1	11/14/2012	I1
Elementary School: DF	4, 5, 6	perpendicular	736	2.0	0.29	0.041	172	T6	9/10/2012	-

Appendix Table U2 shows discharge (Q) values estimated for the drainfield areas. At the high school and elementary school the K values were averaged from drainfield piezometers; the K values were estimated by Smith (2013). At Residential 100 the K values were estimated by Iverson (2013) and at the education center the K values were estimated using the lowest K_{sat} estimation obtained from the NRCS (2015). The area (A) was calculated using the length of the OWS drainfield trenches at the schools and Residential 100; at the education center the width of the drainfield trench was used because it was perpendicular to the direction of the groundwater flow path.

Discharge estimated from OWS parameters and Water Quality Data							
Focus Area	**Q (m^3/yr)**	**Q (m^3/d)**	**K (m/d)**	**dh/dl**	**DF width(m)**	**Depth (m)**	**A (m^2)**
High School: DF	349.87561	0.2251	1.244	0.001373	38	3.47	132
Elementary School: DF	572.98485	0.5483	0.472	0.006296	30	6.15	185
Education Center: DF	62.831201	0.1299	0.35	0.014865	6.5	3.84	25
Residential 100: DF	78.746818	0.4615	0.3	0.040566	24	1.58	38

Appendix Table U3 shows the estimated groundwater velocity for the schools, education center and Residential 100. At the schools the K values were averaged from drainfield piezometers and K values estimated by Smith (2013). At Residential 100 the K values were estimated by Iverson (2013) and at the education center the K values were estimated using the lowest K_{sat} estimation obtained from the NRCS (2015). The dh/dl values were calculated for the piezometers listed in the table; average head values used in the dh/dl calculations are listed in Appendix Table E3.

Estimated Groundwater Velocity						
Focus Area	**Velocity (m/yr)**	**Velocity (m/d)**	**K (m/d)**	**dh/dl (m/m)**	**Specific yield (n)**	**dh/dl Calculation Piezometers**
Elementary School	**22.5**	**0.063**	**0.472**	**0.0286**	**0.22**	**3, 6, 12**
High School	**12.5**	**0.035**	**1.244**	**0.0089**	**0.32**	**7, 12, 21**
Education Center	**5.5**	**0.015**	**0.35**	**0.0087**	**0.20**	**2, 3**
Residential 100	**9.5**	**0.026**	**0.3**	**0.0173**	**0.20**	**101, 103**

Appendix V: Water Level relationship with CCR survey resistivity values and groundwater specific conductivity

For this section, only water level values collected from background (BG) and drainfield (DF) piezometers on survey dates were utilized (Appendix Table F1). On all survey dates the average water level collected from piezometers within the drainfield and background areas ranged from relatively shallow water tables at the high school (1.5 mbgs; n=42) and Residential 100 (0.5 mbgs; n=20) to deeper average water tables at the elementary school (4.3 mbgs; n=31) and education center (3.1 mbgs; n=22) (Appendix Table V1). The range in water table values across background and drainfield sites during survey dates were 0-.9 mbgs for Residential 100, 2.4-4 mbgs for the education center, 3.6-6 mbgs for the elementary school and 0.8-2 mbgs for the high school.

Appendix Table V1 shows the site, date, total sample number (n), average water level (mbgs), average background water level (mbgs), the background sample number (n), average drainfield water level (mbgs), depth to the bottom of the trench (DTBT), and the drainfield sample number for each site survey date. All water levels are given in mbgs units. Mann- Whitney p-values for background (BG) vs drainfield (DF) groundwater specific conductivity (µS/cm) and resistivity (Ω.m) comparisons. The R^2 regression analysis of Log resistivity vs. groundwater specific conductivity for each survey date are given. Average BG and DF µS/cm and Ω.m are provided. The * marks dates in which additional transect Ω.m and µS/cm values were used at the schools.

			Average BG and DF Water Level Data						BG vs. DF			Average BG and DF Data			
Site	**Date**	**n**	**Water Level**	**BG water level**	**BG n**	**DF water level**	**DTBT**	**DF n**	**µS/cm p-value**	**Ω.m p-value**	**R^2**	**BG µS/cm**	**BG Ω.m**	**DF µS/cm**	**DF Ω.m**
Res-100	7/16/2012	7	0.381	0.709	2	0.251	0.50	5	0.3329	1.0000	0.00	192	85	291	88
	11/16/2012	6	0.399	0.648	2	0.274	0.50	4	0.8170	0.2472	**0.71**	245	144	299	96
	3/27/2013	7	0.571	0.783	2	0.486	0.50	5	0.5613	0.8465	0.34	206	107	274	115
EC	3/23/2012	4	3.534	3.042	1	3.698	0.45	3	-	-	0.01	28	221	64	291
	9/4/2012	6	2.681	2.368	2	2.837	0.45	4	0.4875	0.4875	**0.85**	167	177	153	182
	11/29/2012	6	3.202	2.839	2	3.383	0.45	4	0.1052	1.0000	0.02	104	92	158	128
	4/17/2013	6	3.274	2.923	2	3.450	0.45	4	0.8170	0.4875	0.02	90	184	137	386
ES	3/25/2013	6	4.257	4.080	2	4.346	1.00	4	0.1052	0.1052	0.35	121	1464	679	127
	9/10/2012	6	3.912	3.700	2	4.018	1.00	4	0.1052	0.1052	0.58	118	2474	669	26
	9/10/2012*	13	4.368	4.243	4	**4.523**	1.00	9	**0.0069**	**0.0069**	**0.05**	91	1453	707	78
	11/19/2012	6	4.430	4.785	2	**4.426**	1.00	4	0.1052	0.1052	**0.91**	118	3571	478	149
HS	4/10/2013	11	1.626	1.193	3	1.788	0.90	8	0.0189	0.1025	0.72	137	1449	596	61
	9/7/2012	11	1.362	0.953	3	**1.516**	0.90	8	**0.0053**	**0.0101**	0.51	97	1741	340	129
	9/7/2012*	21	1.321	0.988	8	1.526	0.90	13	0.0502	0.0189	0.61	68	1672	284	598
	11/14/2012	10	1.560	1.325	2	**1.618**	0.90	8	0.0502	0.0502	**0.85**	113	1809	380	75

Appendix Table V1 was used to assess the water table and the relationship between resistivity and groundwater specific conductivity across background and drainfield locations on each survey date. Appendix Table V1 was also used to correlate water table highs and lows with changes in resistivity and groundwater specific conductivity. In Appendix Table V1 R^2 values were obtained from a regression analysis: Log resistivity vs. groundwater specific conductivity completed on individual survey dates at each site. The R^2 values were used to assess the relationship between the groundwater specific conductivity values collected using an YSI or TLC meter with the resistivity values collected from CCR surveys on each survey date. Corresponding average water table data for each survey date was provided in order to assess if the water table depth may have influenced resistivity sensitivity.

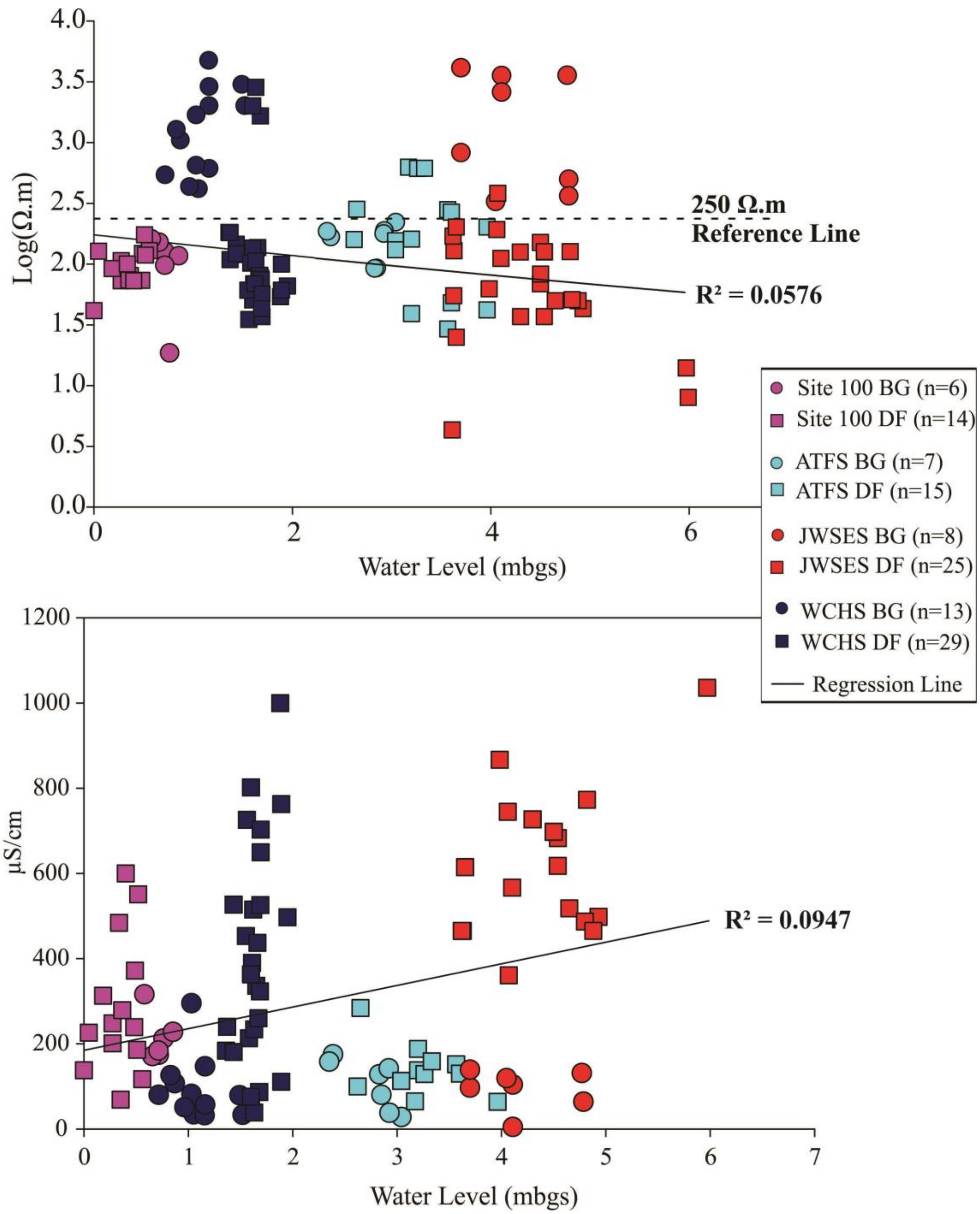
The regression analysis Log resistivity vs groundwater specific conductivity R^2 values for each survey date were consistently higher at the high school followed by the elementary school, Residential 100, and the education center. The high school and education center had the highest wastewater inputs and the water table was shallowest at the high school relative to the elementary school.

Smith (2013) found that seasonal changes in water table depth influenced drainfield groundwater specific conductivity and resistivity values at the schools**.** Researchers found that recharge from rainwater caused the water table to rise and resulted in hydrodynamic dispersion and dilution of dissolved ions that decreased groundwater specific conductivity and increased resistivity values (Smith 2013). The rainwater recharge had a stronger influence on groundwater specific conductivity and resistivity at the high school due to the site’s shallow water table relative to the elementary school (Smith 2013). Smith (2013) found that the sites with deeper water-tables may experience a lag time associated with recharge, which may decrease the sensitivity of resistivity measurements to detect temporal variations in groundwater quality (Smith, 2013). In the current study, there were not enough surveys conducted during the summer months to assess the seasonal influences on groundwater specific conductivity and resistivity. Future research may conduct CCR surveys during the dry season, most often the summer, in order to obtain a stronger resistivity response to expectedly larger contrasts in groundwater specific conductivity.

Overall, the State Climate Office of North Carolina states that the average rainfall does vary throughout the year. Generally, the wettest season is summer during this time rainfall is more variable (SCONC, 2015). The wettest month is July (SCONC, 2015). The driest season is autumn and the driest month is November (SCONC, 2015). Rainfall in the winter and spring months is generally more regular and evenly distributed compared to the summer months (SCONC, 2015). In the current study the highest R^2 values and strongest resistivity responses to groundwater specific conductivity occurred in September and November (Appendix Table V1).

The strongest Log resistivity vs groundwater specific conductivity regression analysis R^2 values were obtained on 11/14/2012 at the schools when the average drainfield water table was approximately 1.618 mbgs at the high school and 4.426 mbgs at the elementary school (Appendix Table V1). At the high school on 9/7/2012* both of the groundwater specific conductivity and resistivity data sets were significantly different across background and drainfield locations ($p < 0.05$).

A scatter plot was used to compare Log resistivity values with corresponding water levels collected across each site in order to assess the spatial change in water level across the sites (Appendix Figure V1).



Appendix Figure V1, shows a scatter plot of pooled data Background (BG) and drainfield (DF) location Log resistivity (Ω.m) vs water level (mbgs) and background and drainfield groundwater specific conductivity vs water level (Appendix Table F1). In the figure Residential 100 and the high school have relatively low water levels relative to the elementary school and the education center.

In Appendix Figure V1, the high school and Residential 100 have shallow water levels relative to the education center and the elementary school. In Appendix Figure V1, the resistivity (top plot) and groundwater specific conductivity (bottom plot), show a noticeable offset in the water levels collected from background (circle) vs. drainfield (square) locations at the high school and Residential 100. Additionally with the exclusion of 2 outlier drainfield values the education center also shows some variability in water levels collected from background and drainfield locations.